Rocky Mountain Space Grant Observatory

Final Report

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Abstract

The goal of the Space Grant Internet Telescope Network (SGITN) is to make astronomical instruments available to people around the world through the internet. This means that students all around the world can access telescopes all around the nation.

This network of telescopes will allow students to use expensive equipment without the setup cost. This will also allow students in locations where sky observations are not possible to gain interest in space by a click of their mouse.

All telescopes are in permanent locations, and "using them" means sitting down at an internet-connected computer, logging into the instrument, and starting to take pictures. This eliminates literally hours of set-up and tear-down work at the beginning and end of the observing session, and it's actually possible to do other things (like your homework) while taking long exposure images.

The Rocky Mountain Space Grant Observatory located at Utah State University is one of six telescopes in the SGITN. The others are located in North Dakota and South Dakota.

Current Group Members

Systems Lead

Scott Farnsworth

Weather

Matt Pine, Brok Thayn, Monica Berrett

Dome Operations

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Telescope

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Former Group Members

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Controls

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Telescope

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1.0   Introduction

Utah State University (USU) is currently working on a web based telescope in conjunction with other universities and organizations around the world. Each university or organization will have their own telescope, making a network of telescopes around the world. These telescopes will display the images they observe on the web in real time. Students will be able to login to the website and reserve the telescope for a predetermined time. The student using the telescope will have the ability to direct the telescope wherever they see fit. Having a network of telescopes allows the user to look into space during the daytime by accessing a telescope in another part of the world, for example a telescope in Europe or Asia. One of the concerns with the USU telescope is how to protect it from the environment if the system is completely operated remotely. The dome needs to be automated and programmed to close when bad weather arises.

2.0 Problem Statement

An overview of the project is shown in the figure below. The flow of this report will be broken down by subsystem. The weather subsystem includes sensors and their communication with the PLC (Programmable Logic Controller) along with tracking and logging data. Dome control subsystem consists of the motors, sensors and programs coded in latter logic for the PLC. The telescope subsystem covers the telescope operations, operating and interfacing the camera, the equatorial wedge, and alignment issues.
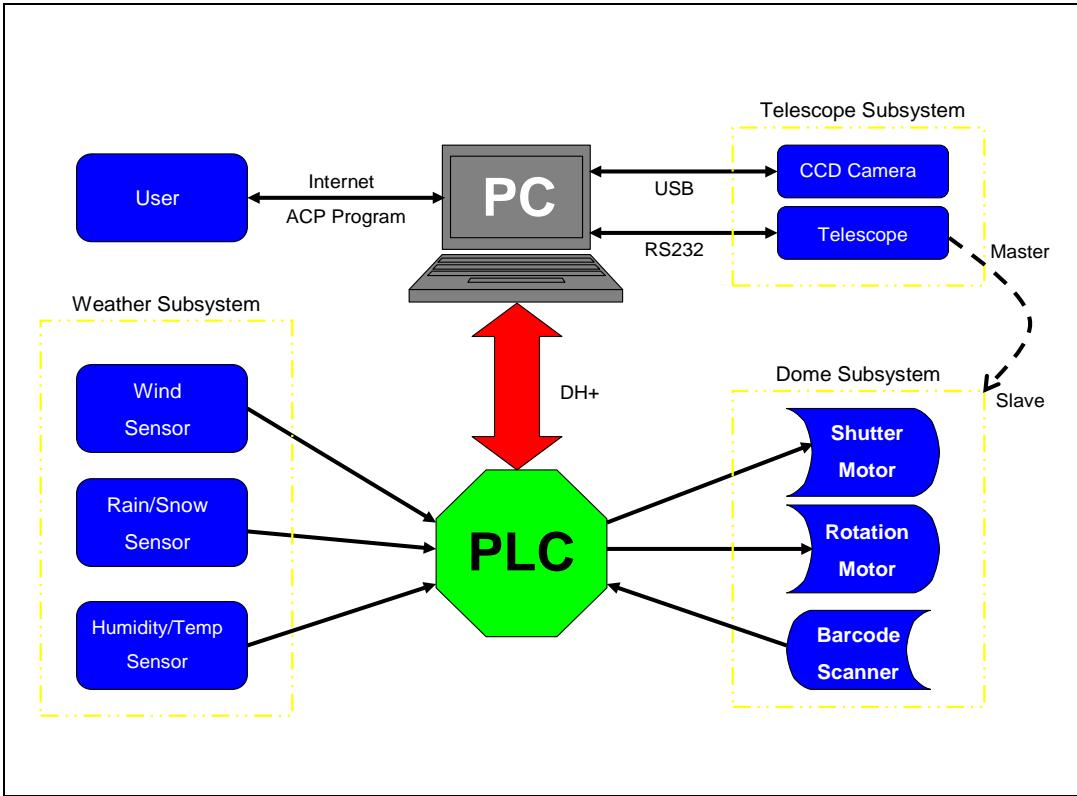
Figure 1: Overall System

The current Rocky Mountain Space Grant Observatory is completely manually operated. One has to get onto the roof of the Engineering Laboratory EL building and manually flip the switch to open the observatory. This can be very tedious and time consuming. The user has to stay up in the observatory the whole time he or she wants to use the telescope in case bad weather occurs, to shut the dome in order to preserve the telescope. This project will convert the dome into a fully automated system.

There are a few constraints that will affect the design. There is an existing dome, two existing dome motors, and three sensors that have to be used in the design. The subsystem has to be able to work in all types of weather situations taking place in Logan, Utah.

A team of electrical engineering students from Utah State University have developed the design and some preliminary implementation to achieve the overall goal of a stand-alone, fully-functional observatory system.

3.0 Project Organization

3.1 Engineering Team

Members of the Observatory team are enrolled and active in a University Electrical-Mechanical Engineering course designed to specialize in Space Systems Engineering. As team members provide personal initiative and experience to the group, the project progresses and members benefit from one another.

The Dome Operations Sub-group works with dome operations including motors, PLC interface, and power issues. The Weather Sub-group relates to design pertaining to weather-related sensors. The Telescope Sub-group deals with aspects of interfacing an automated telescope with computer controlling software. The team works together in designing and testing to plan interfacing and eventual system implementation.

3.2 Semester Timeline

Each of the three groups created a timeline to outline key goals and accomplishments through the progression of the semester. An innovative and helpful program was used to organize the layout of the project, available for free, called Gantt Project.
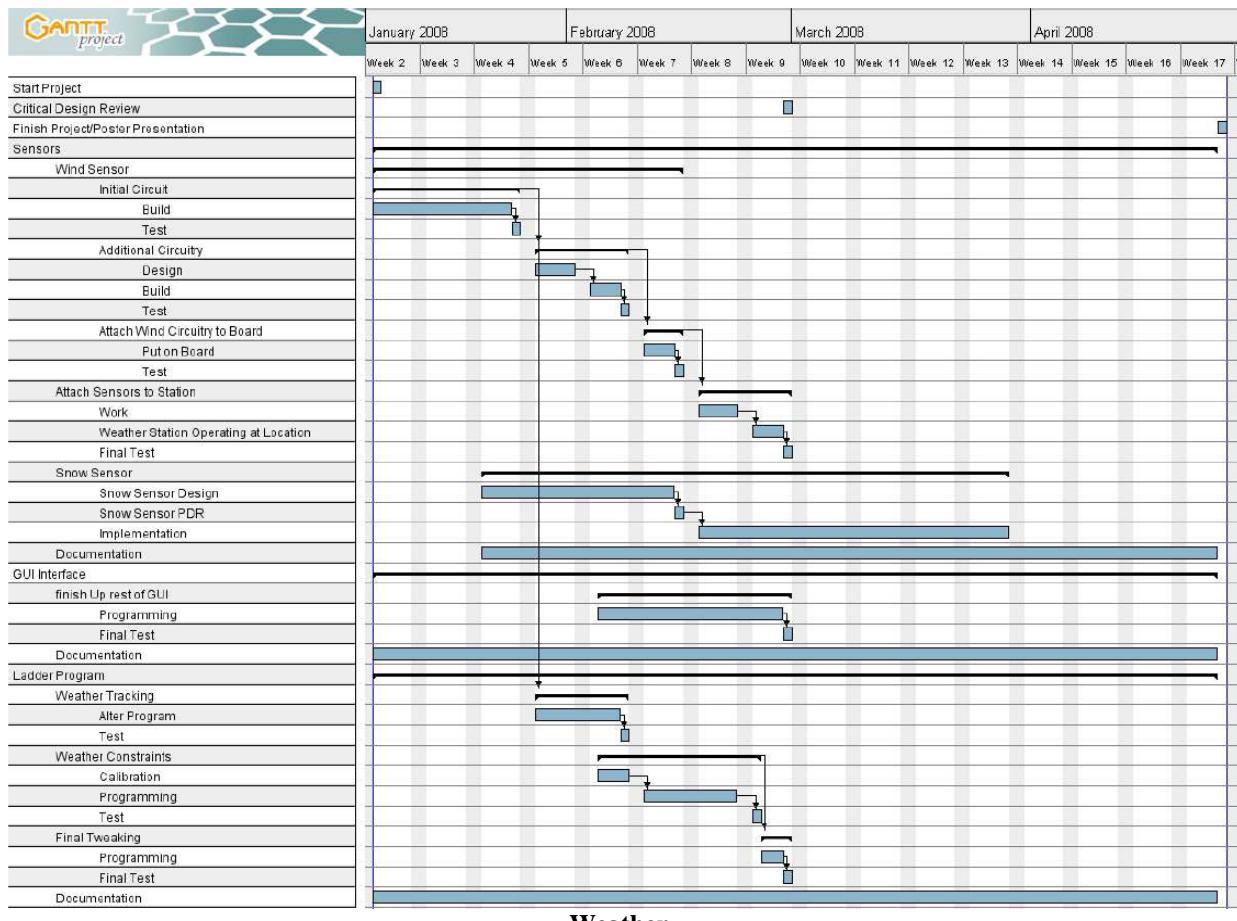
Weather
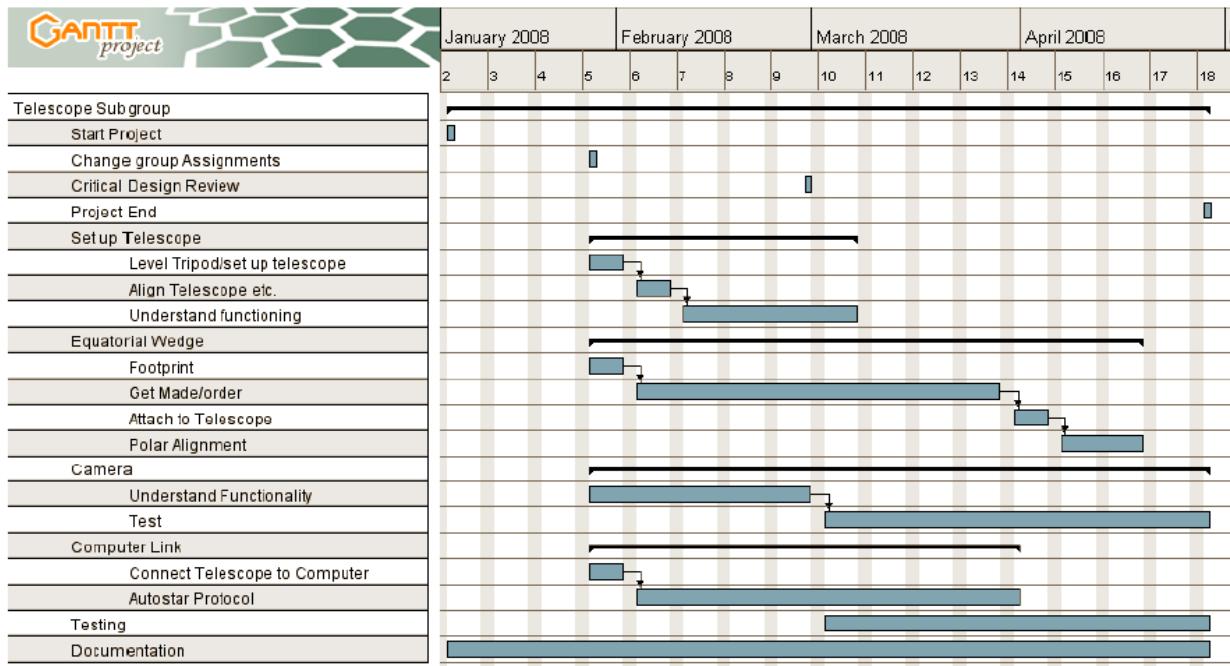
Telescope
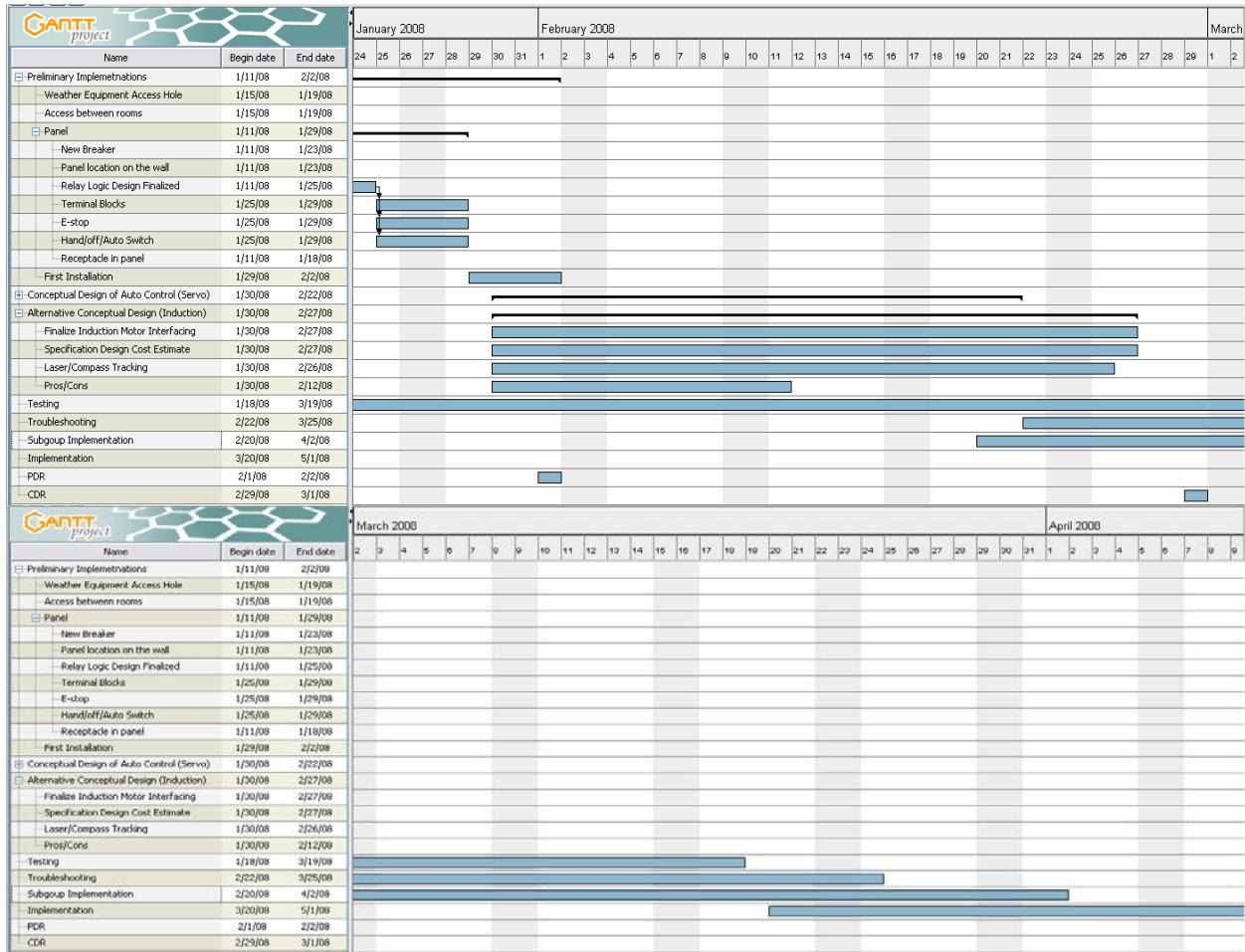
Dome Operations

Figure 2: Gantt Charts

The initial layout of the project included only preliminary preparations and as the group began to ascertain specific needs for the project, additional tasks were added and specific group organization began to take place.

3.3 Cost Estimation

Below is a table which consists of a parts list and the associated cost for the rotation of the dome. This table only includes parts needed and does not include any engineering time spent on the project.

Subgroup	Item	Brand	Model	Qty	Price	Shipping	Total
telescope	USB extender	Vigor	VAD-1120	1	$39.99	$4.98	$44.97
telescope	Telescope	Meade	LX200R 14"	1	Prior Equipment	$0.00	
telescope	Ultra Wedge*	Meade	LX200R 14"	1	$499.95	$15.00	$514.95
telescope	CCD camera	Meade	Deep Sky Imager PRO II	1	Prior Equipment	$0.00	
weather	Temp/Humidity Sensor	Campbell	HMP45C	1	$214.00	$0.00	$214.00
weather	Anemometer	Young	03101 R.M.	1	$216.00	$0.00	$216.00
weather	Rain Gauge	Campbell	TE525	1	$145.00	$0.00	$145.00
weather	Snowfall Adapter*	Campbell	CS705	1	$460.00	$0.00	$460.00
weather	6' Tripod	Campbell	N/A	1	$420.00	$0.00	$420.00
weather	Radiation Shield	Campbell	N/A	1	$175.00	$0.00	$175.00
weather	Cross Arm	Campbell	CM 204	1	$78.00	$0.00	$78.00
weather	Right Angle Mount Kit	Campbell	CM 220	1	$21.00	$0.00	$21.00
weather	Circuit for Anemometer	Various	N/A	1	$3.50	$0.00	$3.50
dome	PLC 5/25 with misc. I/O Cards	Allen Bradley	PLC-5/25	1	Donated Equipment		
dome	PLC Software	Allen Bradley	RSLogix, View,Linx	1	Donated Equipment		
dome	Schneider Hand-Off_Auto	Schneider	9999SC8	1	$138.95	$0.00	$138.95
dome	20 Amp QO Breaker	Square D	QO20	1	$12.00	$5.00	$17.00
dome	Dayton 24 Volt Coil 10 Amp Relay	Dayton	5ZC11	10	$5.65	$10.00	$156.50
dome	Disconnect Switch	Square D	L211N	2	$14.00	$0.00	$28.00
dome	Terminal Blocks	Phoenix Contact	(Purchased)	30	$0.34	$0.00	$10.20
dome	24 VAC, 8 Amp Transformer	Triad	(Donated)	1	Donated Equipment	$0.00	
dome	Barcode Sensor	Symbol	(Donated)	1	Donated Equipment	$0.00	
dome	Pushbutton E-stop	Square D		1	$11.00	$0.00	$11.00
dome	Motor Soft Start	Telemecanique	Altistart 01	1	$99.00	$7.00	$106.00
dome	PLC ASCII Card (RS-232)	Allen Bradley	1771-DA	2	$25.00	$5.00	$60.00
dome	Indicator Light	Square D	Square-D 9001	1	$19.99	$0.00	$19.99
dome	8 Amp and 5 Amp Fuse & Holders	Buss	CC/Dule Elmt	2	$5.00	$5.00	$20.00
dome	THHN Wire as needed (in feet)	Any	THHN 14 AWG	100	$0.30	$5.00	$530.00
dome	Limit Switches	Allen Bradley	A02T	2	$10.00	$5.00	$30.00
dome	UPS	Power Waire	5115 1000VA	1	$300.00	$20.00	$320.00
dome	Drive Wheel	True Wheel	True Wheels	1	$50.00	$5.00	$55.00
dome	PS/2 to RS232	Awce	Awce #GP-2	1	$50.00	$5.00	$55.00
* - still need to purchase					**Total Cost:**		**$3,850.06**

4.0   Weather Subsystem

4.1   Sensors

4.1.1 TE525 Rain Gauge

In order to protect the telescope from precipitation a rain sensor is incorporated into the system. USU already has the TE525 rain gauge sensor so that is being used. The TE525 works as a simple switch. When rain fills up the tipper, it tips and closes a switch. Each tip represents 0.01 inches of rain have fallen. The input to the TE525 will be 5VDC. The output signal will be a 5V pulse wave which will be directly inputted into the PLC's TTL logic board where it will count the pulses (frequency). The PLC will count the pulses over a predetermined amount of time to determine if it is safe for the dome to open (see Weather Research section). During the winter a snowfall adaptor will be placed on top of the TE525 which will melt the snow to have the TE525 work if it were raining.

4.1.2 03101 R.M. Wind Sensor

In order to protect the telescope from debris in the air an anemometer is incorporated into the system. The anemometer that is being used is the 03101 R.M. Wind Sensor. This sensor requires no input voltage to power the sensor; it generates its own AC sine wave. This, however, is a minor problem as the PLC cannot accept a low frequency sine wave input. To convert the sine wave output to a square wave a LM358 operational amplifier and a 2N3904 BJT were used. The operational amplifier is used in an inverting non-linear configuration with a gain of ten. The BJT is connected to the output of the op-amp to generate the 5V pulse wave. The PLC counts

the number of pulses per second (frequency) and uses a simple equation to produce the wind

speed. The PLC will then close the dome when a predetermined threshold is reached (see

Weather Research section). Below is the schematic for the sine wave to square wave circuit.
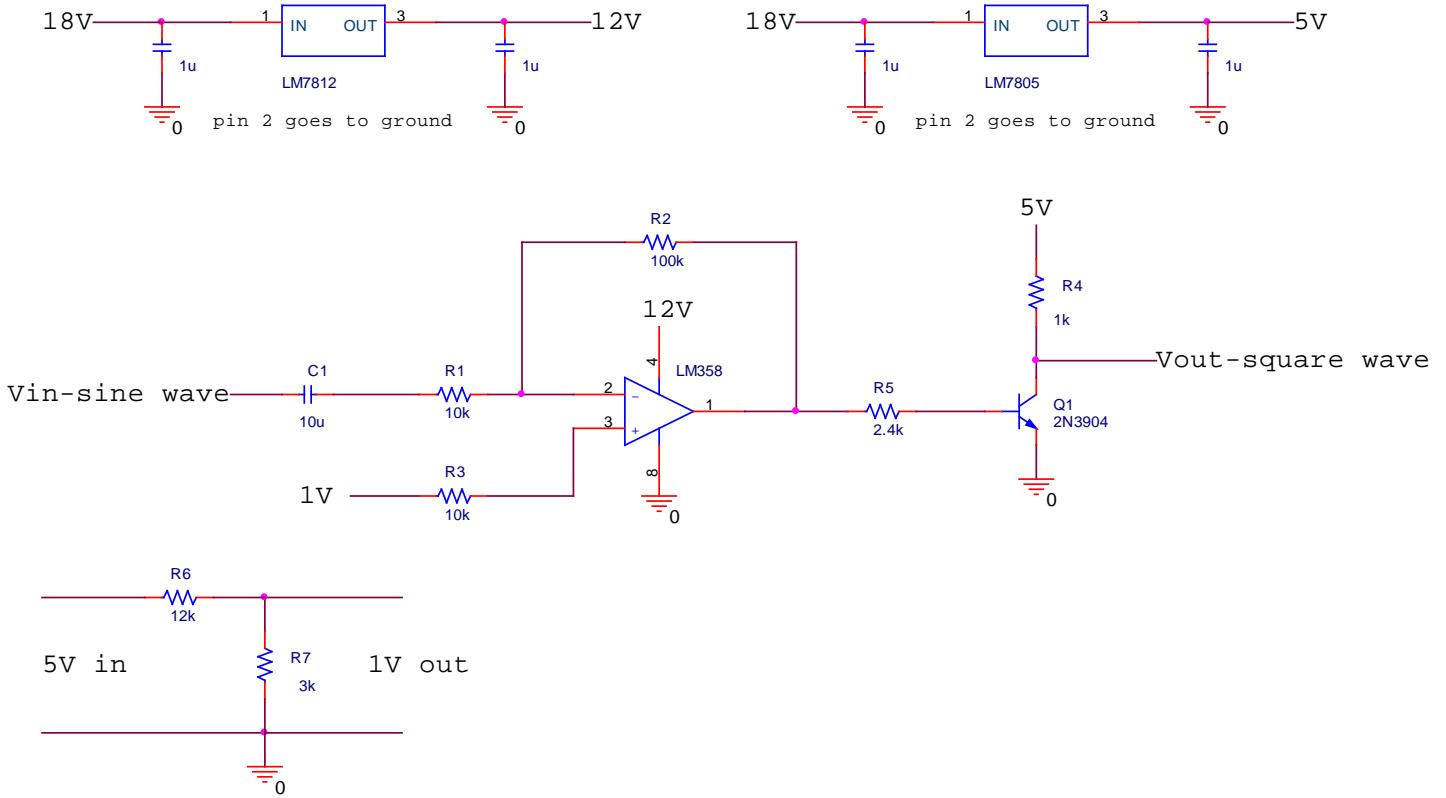
Figure 3: Sine Wave to Square Wave Circuit

4.1.3 HMP45C Temperature/Humidity Sensor

In order to protect the telescope from severe cold and for early storm detection a

temperature and relative humidity sensor is incorporated into the system. The HMP45C

Temperature/Relative Humidity sensor is being used for this application. The recommended

input voltage to the sensor is 12VDC. To power the sensor the 12V voltage regulator circuit is

used (see power section). The output of both the temperature signal and the relative humidity

signal ranges from 0.001V to 1V. These output signals are also analog. The PLC has an analog

input card that can read voltages from 0 to 5 volts with a precision of 12 bits (4096 values). This

leaves 819 values to read the 0.001 to 1 volt (1000 values). This will loose some accuracy of the

temperature and relative humidity reading but not a significant amount for the needs of this

system. The data loss is somewhere on the order of $\pm$ 0.2 degree and $\pm$ 0.2 % humidity. The

PLC will read in these values and compute the temperature and relative humidity and, based on

predetermined data, will close the dome (see Weather Research section).

4.1.4 Sensor Manuals

Below is a table of links to the sensor manuals. These can also be found on the project

website http://rmspacegrant.googlepages.com.

Sensor	Manual
TE525 Rain Gauge	www.campbellsci.com/documents/manuals/te525.pdf
03101 R.M. Wind Sensor	www.campbellsci.com/documents/manuals/03001.pdf
HMP45C Temp./Hum.	www.campbellsci.com/documents/manuals/hmp45c.pdf

Table 2: Links to Sensor Manuals

4.1.5 Weather Research

Some weather research has been performed to help determine the thresholds of the

weather conditions in order for the dome to close. The dome will be closed if any of the

conditions occur: humidity rises above 95%, the rain bucket ever tips, or the wind gets above 40

miles per hour. If any of theses weather conditions occur the dome will close and continue to

read the sensors to see when it is okay to open the dome again.

4.1.6 Sensor Set Up

All of the sensors were mounted on an anchored tripod on top of the EL building at USU.

The sensors were then hooked up to the board with the circuitry found in figure 1 which is

connected to a wire to the PLC. The board was then encapsulated in a water tight box to keep it protected from the elements.

4.1.7 Sensor Power

To power the sensors a 120VAC to 12VDC transformer was used. The actual output of the transformer was 18VDC.   In order to get the desired 12VDC, for the HMP45C Temperature/Humidity Sensor, and 5VDC, for the TE525 Rain Bucket, two simple voltage regulators were used. The LM7805 was used to get the 5VDC and the LM7812 was used to get the 12VDC. Below are the schematics for the voltage regulator circuits.
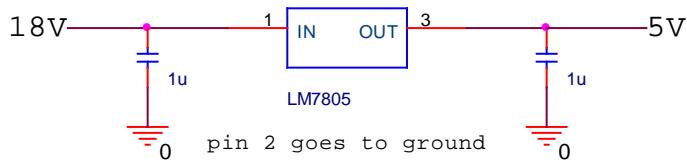
Figure 4: 5 Volt voltage Regulator
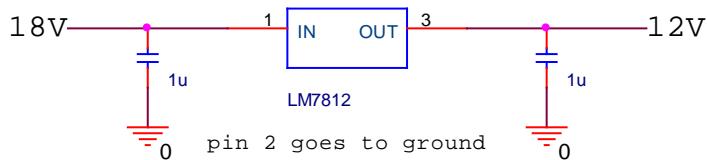
Figure 5: 12 Volt Voltage Regulator

The capacitors are used to dampen any voltage spikes.

4.2   Software

The PLC uses RSLogix5 software to write the control program for the PLC. RSLogix5 is a Windows based ladder logic programming tool. It visually shows the ladder program as well as contains several other tools to make the programming process simpler. It was a little difficult

to use at first because of the lack of available online documentation as well as the documentation that came with the installation. But the program does contain a very well organized help section. From that the program was able to be used.

The first difficulty with the program and PLC was getting the modules to work. The analog input module needed to be calibrated. The calibration was done by hand, looking through manuals and the documentation. That did not work. Then it was discovered that the program RSLogix5 will put the correct calibration lines of code into the program. Knowing this before hand would have saved quite a bit of work.

Ladder logic is not executed sequentially as is done in C++ and other programming languages. Each "rung" or instruction on the ladder is executed at the same time. The best way to help understand ladder logic is to think of each rung as a logic expression. If the first condition(s) is (are) true then the instruction will be executed. If a rung is empty before an instruction that is considered as a true value and the instruction will always be executed each time the program is swept.

4.2.1 Weather Program

The weather program is the first step in accomplishing tracking of the weather conditions around the dome and closing the dome in inclement weather conditions. This program is set up to take the sensor data and interpret that into the corresponding measurement value. Then the GUI / RSView32 program can take those values off of the PLC and log them into metadata on the computer. The next step in the programming process will be incorporating the dome open and close routines which will be discussed later on.

There are four weather sensors that are being used temperature, humidity, rain and wind. The specifics on each sensor are found in the sensor section of this report. These four weather sensors are connected to the PLC using the differential analog input module. These four inputs have been set up to give a zero to five volt signal; the analog module has been set up to accept this voltage range. The analog input module is a 12-bit A/D converter as has been mentioned above. Therefore the weather signals are broken down into numbers ranging from 0 – 4095. Zero represents zero input voltage and 4095 represents five volts. That gives a resolution of 819 per volt.

The temperature and humidity sensor gives a voltage value depending on the measurement. The rain sensor gives a pulse per 0.01 inches of rain fall. The wind sensor and circuitry will also give a pulse signal, one per revolution. The weather program must take the temperature and humidity data from the analog module and convert that to the actual voltage given by the sensors. Then it can use the conversion equations supplied with the sensors to give the corresponding weather condition reading. But as for the wind and rain sensor the program must compare if the input is over a certain amount to signify that a pulse was sent from the sensor. The program must accumulate the total number of pulses sent in a certain amount of time. Then convert that into the wind speed and precipitation amount.

The program is laid out in this fashion. First are the calibration rungs to set up the analog input module. That is followed by procedures to get the current day and hour from the PLC for precipitation time tracking as well as procedures to update that information every hour and day.

Next is the rain counter and precipitation amount calculation. The precipitation is set up to record the amount received in the hour as well as in the whole day. The wind timer, counter and calculations come after the rain section. The wind sensor calibration equation is set up to

calculate the wind speed by how many revolutions per second it spins. Therefore the wind timer will give the time aspect and the wind counter will count how many revolutions in that time. Then the calculations will give an average revolution per timer time (ten seconds) and that will be used in the calibration equation to give the wind speed. Last and not least are temperature followed by humidity measurement calculations. These are done by converting the A/D value to the voltage value sent by the sensor. Then the program puts that value into the calibration equation to give the measurement value.

Below is the weather program as it is laid out in RSLogix5. That is followed by a list of the variables used in the PLC memory/IO and their address location, symbol and description.

Rungs for 1771-IL module at rack 0, group 2, slot 0

12 Bit Isolated Analog Input

Rung 0000

Power up bit
N9:10
0

Block Transfer Write
configure bit
B10:0
0

First scan
of ladder
or SFC
step
S:1
15

Block Transfer Write
control block
N9:5
15

Block Transfer Write
control block

```
-BTW-
Block Transfer Write                              (EN)
Module Type   Generic Block Transfer
Rack                           000                (DN)
Group                            2
Module                           0                (ER)
Control Block                 N9:5
Data File                    N9:22
Length                          11
Continuous                      No
              Setup Screen          <
```

Rung 0001

Run Program
RUN
B3:0
0

Block Transfer Read
control block
N9:0
15

Block Transfer Read
control block

```
-BTR-
Block Transfer Read                               (EN)
Module Type   Generic Block Transfer
Rack                           000                (DN)
Group                            2
Module                           0                (ER)
Control Block                  N9:0
Data File                    N9:10
Length                           8
Continuous                      No
              Setup Screen          <
```

Rung 0002

Power up bit
N9:10
0

current hour of the
day
STD_HOUR

```
-MOV-
Move
Source            S:21
                   11<
Dest            N7:10
                   11<
```

Current day of the
month
STD_DAY

```
-MOV-
Move
Source            S:20
                    4<
Dest             N7:9
                    4<
```

19

0003

Run Program
RUN
B3:0
0

Real time
clock HOUR

NEQ
Not Equal
Source A   S:21
            11<
Source B   N7:10
            11<

current hour of the
day
STD_HOUR

MOV
Move
Source   S:21
            11<
Dest   N7:10
            11<

Rain Counter
R_COUNT
C5:1
(RES)

Rain Amount in
inches in 24 hours
R_IN_DAY

ADD
Add
Source A   F8:4
            0.0<
Source B   F8:5
            0.0<
Dest   F8:5
            0.0<

Rain amount in
inches in one hour
R_IN_HOUR

MUL
Multiply
Source A   F8:4
            0.0<
Source B   N7:4
            0<
Dest   F8:4
            0.0<

0004

Run Program
RUN
B3:0
0

Real time
clock DAY

NEQ
Not Equal
Source A   S:20
            4<
Source B   N7:9
            4<

Delay for 24 hour
rain update
information download
R_DAY_DELAY/TT
T4:2
TT

Current day of the
month
STD_DAY

MOV
Move
Source   S:20
            4<
Dest   N7:9
            4<

Delay for 24 hour
rain update
information download
R_DAY_DELAY

TON
Timer On Delay   (EN)
Timer   T4:2
Time Base   1.0   (DN)
Preset   60<
Accum   0<

0005

Delay for 24 hour
rain update
information download
R_DAY_DELAY/DN
T4:2
DN

Rain Amount in
inches in 24 hours
R_IN_DAY

MUL
Multiply
Source A   F8:5
            0.0<
Source B   N7:4
            0<
Dest   F8:5
            0.0<

0006

Rain
R

GRT
Greater Than (A>B)
Source A   N9:17
                    5<
Source B   N7:3
                    250<

Rain Counter
R_COUNT

CTU
Count Up
Counter   C5:1   —(CU)
Preset   1<
Accum   0<   —(DN)—

0007

Rain counter is >= 1
count
R_COUNT/DN
C5:1
] [
DN

Rain amount in
inches in one hour
R_IN_HOUR

MUL
Multiply
Source A   C5:1.ACC
                    0<
Source B   F8:11
                    0.01<
Dest   F8:4
                    0.0<

0008

Wind
W

GRT
Greater Than (A>B)
Source A   N9:16
                    14<
Source B   N7:2
                    1638<

Wind Counter
W_COUNT

CTU
Count Up
Counter   C5:0   —(CU)
Preset   1<
Accum   0<   —(DN)—

0009

Run Program
RUN
B3:0
] [
0

Timer for Wind
Sensor 10 Seconds
W_TIME

TON
Timer On Delay   —(EN)
Timer   T4:0
Time Base   1.0   —(DN)—
Preset   10<
Accum   3<

0010

Wind Timer Done
W_TIME/DN
T4:0
] [
DN

Sensor 10 Seconds
W_TIME
T4:0
—(RES)—

Wind Counter
W_COUNT
C5:0
—(RES)—

Wind Sensor
Frequency
W_FREQ

DIV
Divide
Source A   C5:0.ACC
                    0<
Source B   N7:6
                    30<
Dest   F8:6
                    0.0<

0011

Wind speed without
const
W_MID

MUL
Multiply
Source A   F8:6
                    0.0<
Source B   F8:12
                    1.677<
Dest   F8:7
                    0.0<

21

0012

wind speed
W_SPEED

```
-------- ADD --------
Add
Source A          F8:7
                   0.0<
Source B          F8:13
                   0.4<
Dest              F8:8
                   0.4<
```

0013

Temperature
Conversion middle
variable
T_MID

```
-------- MUL --------
Multiply
Source A         N9:14
                  512<
Source B          N7:1
                    5<
Dest              F8:0
               2560.0<
```

0014

Temperature sensor
voltage
T_VOL

```
-------- DIV --------
Divide
Source A          F8:0
               2560.0<
Source B          N7:0
                 4095<
Dest              F8:1
            0.6251526<
```

0015

Temperature
calibration
Calaclulation middle
value
T_CALABRATION

```
-------- MUL --------
Multiply
Source A          F8:1
            0.6251526<
Source B          N7:7
                  180<
Dest             F8:14
             112.5275<
```

0016

Temperature
TEMP

```
-------- SUB --------
Subtract
Source A         F8:14
             112.5275<
Source B          N7:5
                   40<
Dest              F8:9
             72.52747<
```

0017

Humidity Conversion
middle Variable
H_MID

```
-------- MUL --------
Multiply
Source A         N9:15
                  172<
Source B          N7:1
                    5<
Dest              F8:2
                860.0<
```

22
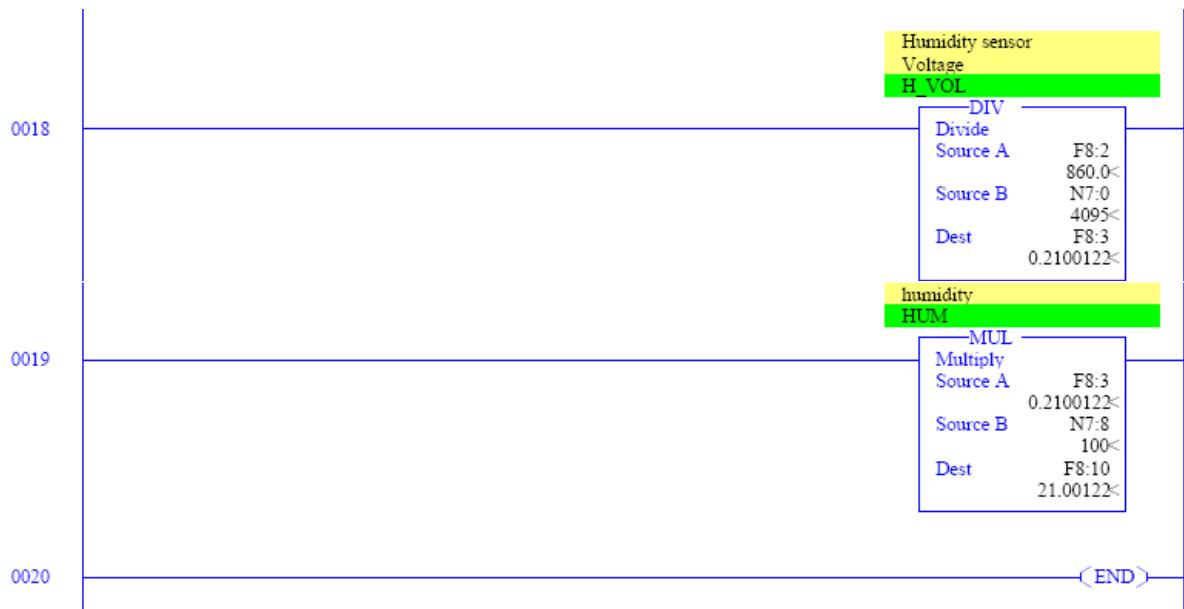
Figure 6: Weather Program Ladder Logic

```
Address          Symbol          Scope     Description


B3:0/0           RUN             Global    Run Program
B10:0/0                                    Block Transfer Write  configure bit
C5:0             W_COUNT         Global    Wind Counter
C5:0.ACC                                   Wind sensor frequency in 30 seconds
C5:1             R_COUNT         Global    Rain Counter
C5:1.ACC                                   Rain Count Amount in one hour
C5:1/DN                                    Rain counter is >= 1 count
C5:2/DN                                    Hour Counter Done
F8:0             T_MID           Global    Temperature Conversion middle variable
F8:1             T_VOL           Global    Temperature sensor voltage
F8:2             H_MID           Global    Humidity Conversion middle Variable
F8:3             H_VOL           Global    Humidity sensor Voltage
F8:4             R_IN_HOUR       Global    Rain amount in inches in one hour
F8:5             R_IN_DAY        Global    Rain Amount in inches in 24 hours
F8:6             W_FREQ          Global    Wind Sensor Frequency
F8:7             W_MID           Global    Wind speed without const
F8:8             W_SPEED         Global    wind speed
F8:9             TEMP            Global    Temperature
F8:10            HUM             Global    humidity
F8:11            R_MUL           Global    Rain calculation calibration number
F8:12            W_MUL           Global    Wind calibration multiplier
F8:13            W_CONST         Global    Wind speed Calibration constant
F8:14            T_CALABRATION   Global    Temperature calibration Calaclulation middle value
N7:0             AD_C            Global    AD input calabration
N7:1             AD_5V           Global    5V AD max voltage
N7:2             W_THES          Global    Rain Greater then Voltage in two's complement
N7:3             R_THES          Global    Rain Theshold voltage in two's complement
N7:4             ZERO            Global    Zero
N7:5             T_CONST         Global    Temperature Calibration equation constant
N7:6             W_SEC           Global    Seconds for wind
N7:7             T_MUL           Global    Temperature Calibration multiplier
N7:8             H_MUL           Global    Humidity calabration multiplier
N7:9             STD_DAY         Global    Current day of the month
N7:10            STD_HOUR        Global    current hour of the day
N9:0                                       Block Transfer Read  control block
N9:5                                       Block Transfer Write  control block
N9:10                                      Read data block
N9:10/0                                    Power up bit
N9:14            N               Global    Temperature
N9:15            H               Global    Humidity
N9:16            W               Global    Wind
N9:17            R               Global    Rain
N9:22                                      Write data block
T4:0             W_TIME          Global    Timer for Wind Sensor 10 Seconds
T4:0/DN                                    Wind Timer Done
T4:2             R_DAY_DELAY     Global    Delay for 24 hour rain update information download
T4:2/DN
T4:2/TT
T4:2/EN
```

Figure 7: PLC Variable/Memory List

4.2.2   Dome Hatch Control

The next step in the dome opening control program is to implement the open and close

routines of the dome along with the verification of good weather conditions for dome operation.

The first part is to include a bit in the PLC that will be set or reset using the computer to signify

that the telescope is in use (set) or not in use (reset). This means to open the dome for operation

or close it because it is not needed at the moment. This variable will be called IN_OPER for in

operation. The next thing is to implement a routine that will always check the weather data to

verify good operating conditions, while the IN_OPER bit is set. If the conditions are good the

dome can stay open and be used otherwise a close dome routine is triggered and executed. After

an inclement weather condition triggers a close dome routine the program will need to wait a

certain amount of time or wait until conditions become optimal again before allowing operation

to resume. The only weather condition that has been quantified as a "close the dome"

specification is if one pulse from the rain sensor is measured. The other conditions temperature,

humidity and wind have not been significantly quantified for good weather operation. The other

values need to be specifically quantified.

The code for the Open/Close function of the dome is described again in the dome operations

section 5.3.2.2. The ladder logic code is given along with more explanation.

4.3GUI (RSView32)

The RSView32 software has the capability of retrieving and monitoring variables located in

the RSLogix5 code. RSView32 is able to do this using a software program called RSLinx

Classic. Although the capability is there to also store information from RSView32 onto the PLC

this project won't be utilizing that feature.

4.3.1 Creating Tags

The first step in monitoring the code is to create a tag for each variable you wish to have

access to. Creating a tag requires the address of the variable (see Figure 8), a type, possible

maximum and minimum values, units, and a scan class. The possible types are analog, digital,

string, and system. The scan class is used to set how often the variables tag will be updated from RSLogix5.

For the weather system six tags were created, one for each of the following variables; run, rain_in_hour, rain_in_day, temp, hum, and wind. All of the tags except run were set as analog, floating point numbers so they can accept a range of values. Run is a digital tag that takes on the values 0 (no go) or 1 (go) and can be used as a system override. All of the tags were set up in the same scan class with a scan time of five seconds. This means every five seconds RSView32 will check the address location for all tags in RSLogix5 and if the values have changed they will be updated in RSView32.

A window called Tag Monitor is used to view the current values of each tag. It is set up and saved as an Excel spread sheet and contains all six tag names, a description, their current value, and their current state. The state refers to if the tag is valid. It could also be undefined or and error if RSView32 cannot find the desired address in RSLogix5. This was used often in the testing phase to make sure the readings RSView32 was acquiring were the correct ones and that they updated when the sensor inputs changed.

4.3.2 Data Logging

RSView32 has a built in data logging functionality that is very user friendly. After some initial set up this feature is very quick and easy to use and changes to meet the users' needs. The following is a list of steps that were taken in order to begin logging the weather data after tags were created.

1. Decide which format to use
2. Decide where to store the data
3. Decide when to create and delete log data

4. Decide what actions will trigger logging data

5. Decide which tags to log data for

6. Decide what to call the model

The data is stored in dBASE IV (.dbf) wide format which is a table type format. This format stores one date, one time, and all the tag values per line. This is a more useful method then the narrow format option for storing periodically changing data. The data files are also stored using long file names. The format is YYYY MM DD NNNN Weather System (wide).dbf where YYYY is the year, MM is the month, DD is the day, and NNNN is the sequential file identifier. This number indicates the sequence files were created in. You can have up to 9999 file sets per day. At midnight, the sequence starts at 0000 again.

The data files will be stored on the hard drive of the desktop computer in the Rocky Mountain Space Grant Observatory. The path they are saved under is C: documents settings/aggie obs/desktop/RSView help/RSView program/weather station/DLGLOG/weather report model. The system is currently set up to keep data log files for 12 months, 1 year, but that can be monitored to see how much space the files require. Adjustments will be made as necessary if adequate space is not available by either deleting files sooner or saving them to a different location.

There are several options available for how frequently to create a new entry in a data file and also when to begin a new file. New files can be created periodically every hour, day, week, or month. Other options are at a specific date and time or event triggered. It was decided to create one new file every day. The other decision is how often to log a new entry in the current file. This can be done at just about any time interval the user would like. The weather system is

set up to log a new entry for each of the six tag variables every ten minutes. So there will be 6 entries each hour and 144 entries in a file with one file per day.

5.0 Dome Operations Subsystem

5.1 Summary of Design Process

The design process consisted of several designs, which were eventually eliminated until the final design was agreed upon by both the customer and engineers. Below is a brief description of designs that were engineered, but not implemented.

5.1.1 Design One

The first design engineered consisted of a stepper motor which would have replaced the current induction motor. Stepper motors are commonly used for control systems. The two big reasons for designing with a stepper motor are because of its accuracy and life span. Stepper motors can be controlled precisely to a specific direction without any feedback information. They are made for quick stop and go movements in either direction while also providing the ability to move for a long directional time span. A stepper motor would provide the system with an exact angel of the domes position allowing the PLC to compare the domes location with the telescopes position. The comparison would take place in the PLC allowing for any correctional position to be output to the stepper motor.

The downside to using a stepper motor, and ultimately the reason for not choosing this design was the cost issue. In order to control a stepper motor a driver is also needed. The total cost for both the driver and the stepper motor selected is $440.

5.1.2 Design Two

The second design consisted of using the already installed induction motor integrated with a bar-code scanner. The purpose of the bar-code scanner is to provide feedback information to the PLC containing the domes position. Bar codes would be placed every five degrees around the dome while the scanner would be mounted stationary by the induction motor. As the dome rotates the scanner would scan the bar codes which contain the position, in degrees, of the dome. The scanner was set to scan at 10Hz allowing for a fast enough scan to ensure the bar codes on the dome would be read no matter how fast the dome rotated. As the scanner read a barcode the position of the dome would be sent to the PLC which would then compare the telescopes position with the domes position. Depending on the accuracy level selected the PLC would send out a rotation signal to the induction motor to align to the telescopes position within the tolerance level.

During the Critical Design Review the customer agreed that this would be a very accurate way to position the dome, however a simpler design was wanted. The consensus of the customer was that there was an easier way to control by using light sensors and that is what was wanted.

5.1.3 Summary of Final Results

Upon customers' request, the design of an array of CdS cells was implemented which includes the induction motor. Below is a brief description of the implemented design, which will further be discussed in detail in following sections.

An account of cost issues the motor used for the final design is the induction motor. As a result of using the induction motors a soft motor starter was purchased and installed to help preserve the life of the motor. This allows the current flow to linearly increase to the motor to

prevent a sudden current spike. The current flow by the soft motor starter can be controlled by the user to allow for optimal control.

As mentioned above an array of CdS cells is used for feedback of the domes position. The array has three positions which are Rotate Counter Clock Wise, Maintain Position, and Rotate Clock Wise respectively. The cells are mounted to the telescope and rotate when the telescope rotates. A laser, mounted to the rotating dome, is used to trigger the CdS cells. Depending where the dome is, the laser will be pointed in one section of the CdS cells. The output will be sent to the PLC indicating the error, or the difference between the telescopes position and the domes position. Through PLC control, the proper output will be sent to the motors allowing for any correctional rotation.

5.2 Problem Analysis

5.2.1 Review of Problem

A computer controlled observatory system will be capable of remote operation through the interfacing design of a programmable logic controller (PLC). The observatory dome must follow the rotation of the telescope as to provide means of visibility and protection of the equipment contained within.

5.2.2 Design Considerations

Upon inspection of the observatory certain design considerations were implemented into the overall design of the project.

5.2.2.1 Limit Switches

The dome has a shutter motor mounted on the rotating dome. A long wire providing power to the shutter motor could easily be wrapped around the telescope if the dome rotates more than 360˚.

The solution to this problem is to add limit switch to the dome. This will prevent the dome from rotating more than 360˚ in a single direction. The cord will wrap itself around the telescope, but not enough to cause any harm or obstruction to the telescope. If a limit switch is hit the dome will rotate close to 360˚ in the opposite direction and continue to follow the telescope. The downside to this solution is that there will be a few seconds of obstruction for the telescope.

5.2.2.2 Motor Delays

While manually rotating the dome the following observations were made. When the induction motor is on and shuts off the dome has built up rotational momentum. It takes anywhere from one to two seconds, depending on how long the motor has been on, for the dome to slide to a complete stop. When the motor is directing the domes rotation in a clock wise rotation and very quickly switched to rotate the dome in a counter clock wise rotation the motor continues to rotate in the clock wise rotation. The same is said in the opposite direction.

The solution came through testing time delays. There needs to be a two second delay before the polarity of the motor can switch and work properly. This time delay takes place in the PLC code. This fix is very important for the limit switches because they require a direct switch in rotation. When a very quick switch is necessary, the time delay will cause the dome to lose any previous momentum and rotate in the proper direction.

5.2.3 Summary of Specifications

The list below contains specific design specifications for the subsystem of the dome rotation. Include in the specifications are power requirements. The power specification do apply to the domes rotation, however does not affect the design of the rotation system.

- Dome follows telescope sufficiently:
    - Maintain telescope field of view
    - 360 degree limits
- Feedback maintains telescope viewable tolerance:
    - 30 degrees
    - Sensor system with greater than 10 degree resolution
- Panel and contained equipment location:
    - Centralized panel safely controls equipment
    - Reduce electromagnetic interference
- Soft Start:
    - Extend motor life
    - Better, more controllable motor implementation
- Safety:
    - NEC (National Electrical Code) Requirements
    - Emergency stop and disconnection features

5.3 Detailed Design, Schematics, and Layout

5.3.1 Motor/Sensor

5.3.1.1 Motor

The motor that is currently rotating the dome is a single phase, 2.9 Amp, Inductor motor, which is shown in Figure 8.

Figure 8: Induction Motor

Inductor motors are designed to run for longer intervals instead of shorter intervals, so in order to prolong the life of the motor a soft starter is going to be implemented. The soft starter allows the motor to be gradually ramped up to full speed by limiting the initial voltage between 30-80% while gradually raising it to full voltage over an adjustable range of one to five seconds; figure 4 shows the Voltage vs. Ramp up times. The soft starter that has been selected is the ALTI3N1, as shown in Figure 9, which gives the above stated functionality. The soft starter will be wired up according to the schematic shown in Figure 11; instead of using buttons for the stop and start functionality as shown in the schematic, the PLC will stop and start the soft starter motor.

Figure 9: Soft Starter
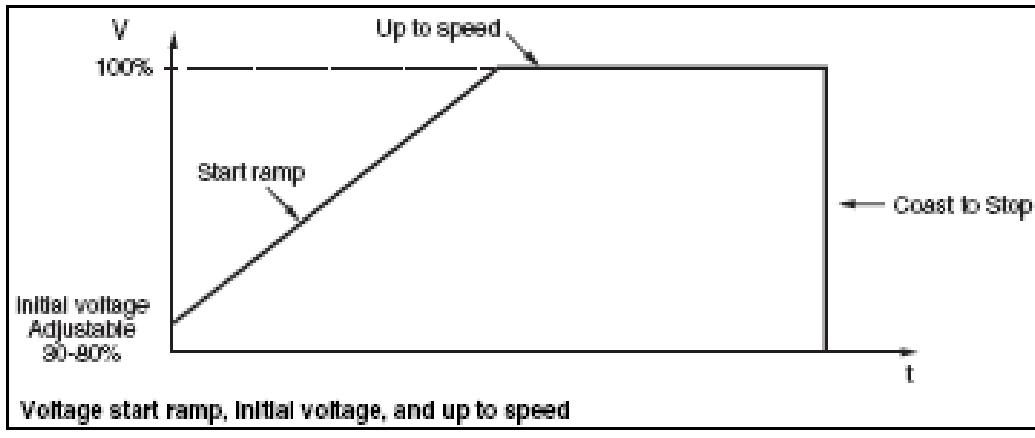
Figure 10: Voltage vs. Time Graph
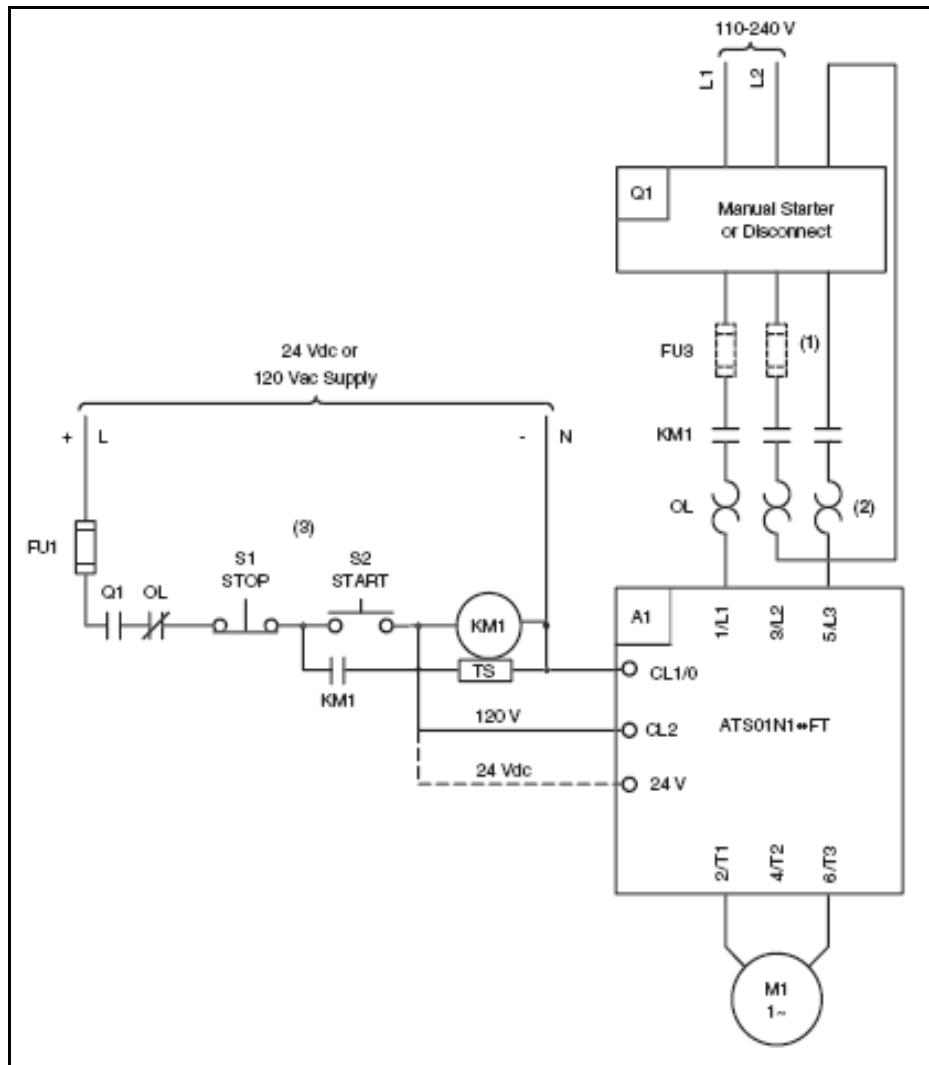
Figure 11: Soft Start Wire Diagram

5.3.1.2 Sensors

The sensing system that has been tested and implemented incorporates the use of CdS Cells (Cadmium Sulfide). Each CdS cell represents two degrees when mounted to the base of the telescope. There is a total viewable window of 48 degrees in which the telescope and view the stars without obstruction from the sides of the dome. The CdS cell array will be mounted to the base of the telescope and a laser will be mounted to the side of the dome which shines on the cells activating a single cell which then relays that information to the PLC notifying it of the status of the domes position. The cells will be organized into three groups of eight cells each. The center eight cells will be the "maintain zone", when in that zone the dome will stay put, the right eight cells will be the "correct clockwise", when in that zone the dome will rotate clockwise until it is in the maintain zone again, the left eight cells will be the "correct counter clockwise", when in that zone the dome will rotate counter clockwise until the maintain zone is reached. These operating zones have been picked because in the case that the telescope starts slewing in any given direction the dome will have time to ramp up the motor and catch up to the rotation of the telescope without obstructing the view of the telescope. The laser will be mounted to the side of the dome 90 degrees from the shutter opening to reduce the amount of light that may shine on the cells accidently activating one and producing false information. The laser will also be mounted one foot high up the side of the dome to avoid obstruction from the motor. Figure 12 shows the setup that will be used for the CdS cells, and laser as well as the viewing angles. Figure 13 shows the circuit diagram for a region of the CdS cells. Each region returns a single TTL signal back to the PLC. The TTL levels are produced by the use of op-amps, the CdS cells generate an analog signal which depends upon the amount of light on the cell, the op-amp then takes that voltage and outputs +5V if the cell has been activated or 0V otherwise. There is one

op-amp for each CdS cell and the output of the op-amps are then taken and checked through a series of OR Gates to see if any cells have been activated, if any cell has been activated then the circuit outputs a TTL level signal to the PLC.
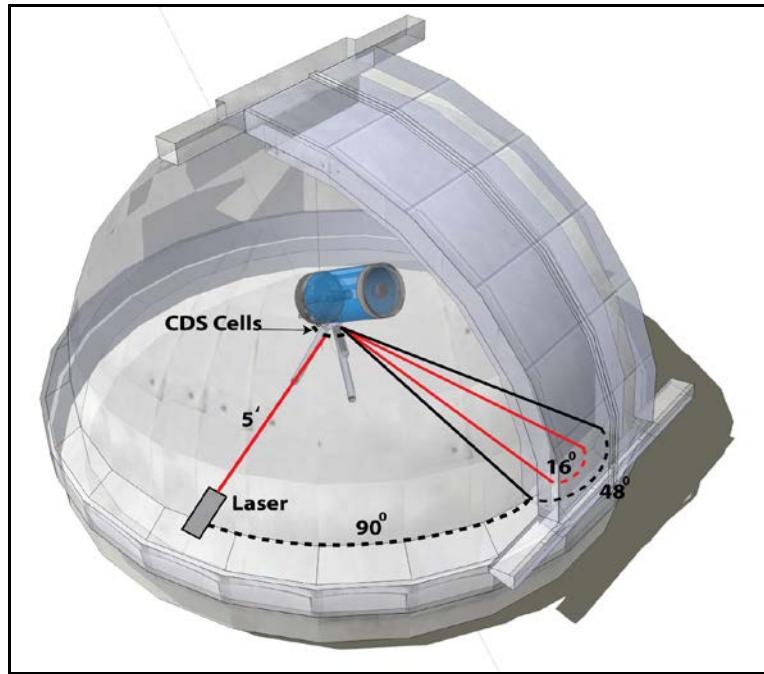

Figure 12: Hardware Setup
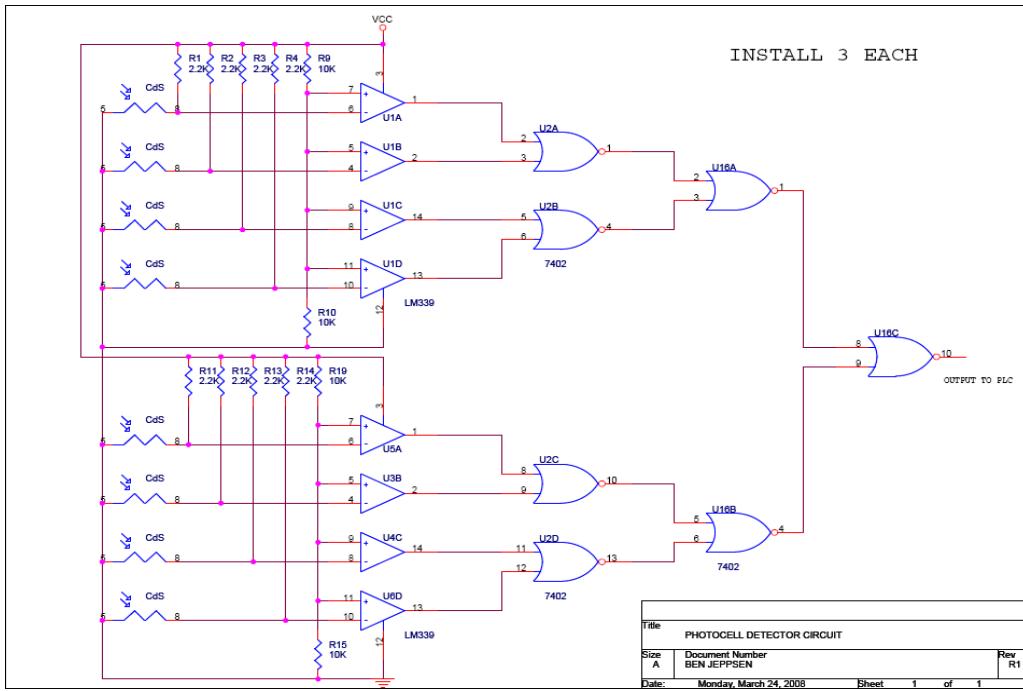
Figure 13: Sensor Circuit

5.3.2 PLC

5.3.2.1 PLC Hardware

The PLC consists of several different parts. For the scope of this project only the parts used will be included. The main body of the PLC is the Chassis: 1771-A2B. This is the body of the PLC which holds all of the necessary cards. The PLC is controlled by the PLC 5/25 Processor: 1785-LT2 with a 1771-P4S Power Supply. Inputs at transistor-transistor logic (TTL) levels are sent into the PLC through the TTL Input: 1771-TTL IGD card. Outputs are controlled by the AC Output: 1771-OAD/C card. Each card has specifications that can be found in the Appendix of this document.
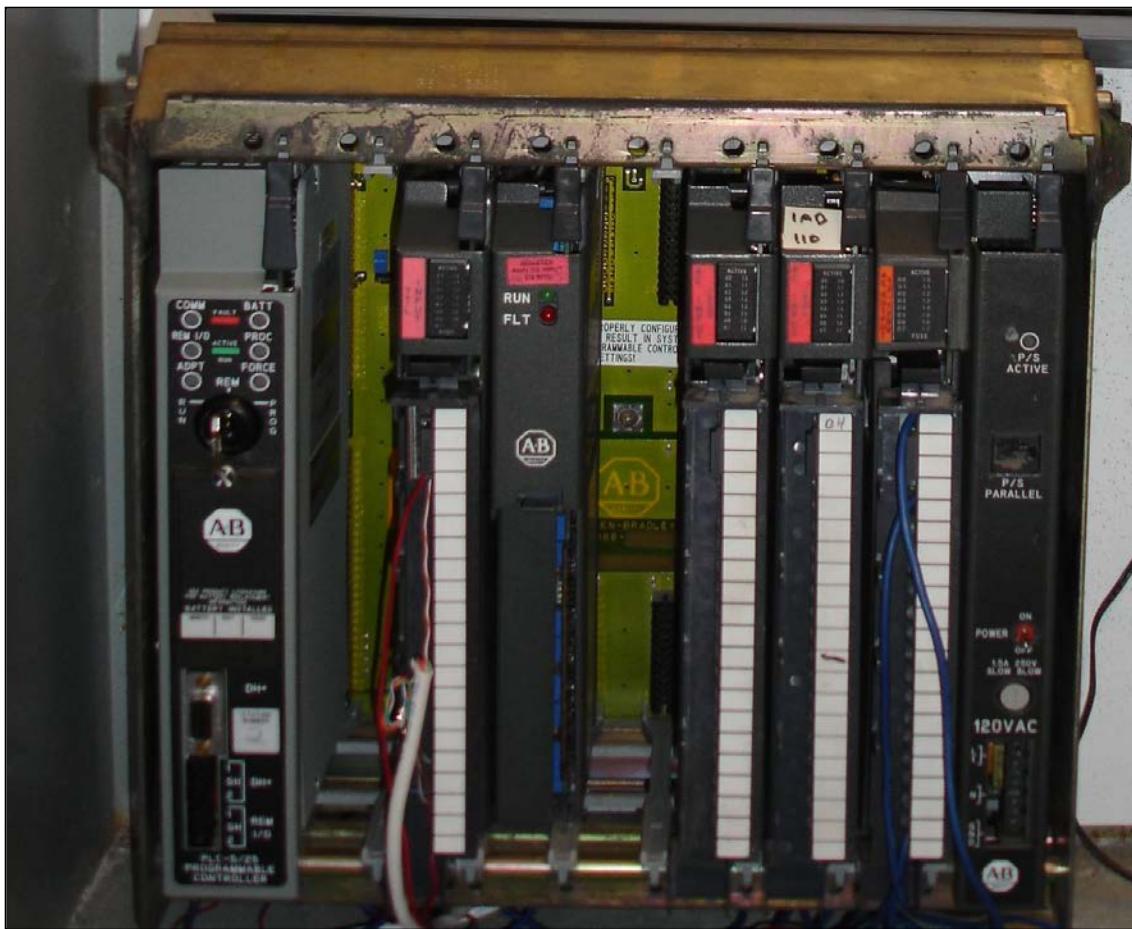
Figure 14: PLC Front

5.3.2.2 PLC System Overview

The figure below depicts how the PLC is coded to operate. The desired position, or the telescopes position, is the input to the system. This position is summed with the systems output which produces the system error. The error is processes and a correction signal is output through the D/A Converter to the dome controls. The dome controls will rotate the motor to eliminate the error of the system. This process will continue until there is a minimal error, within tolerance, in the system.
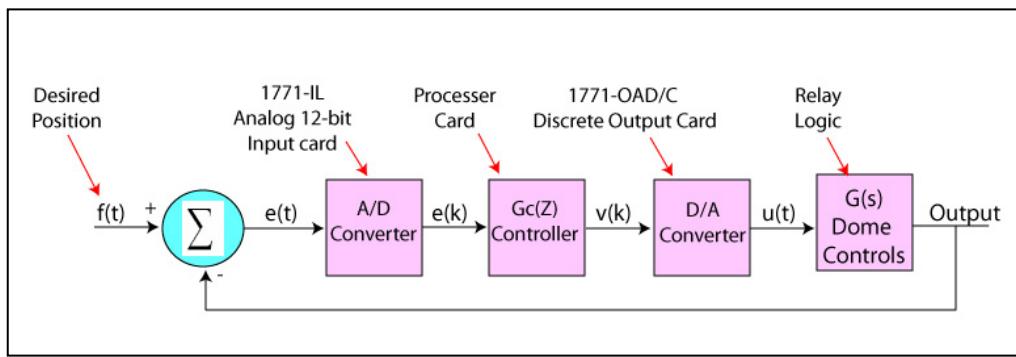

Figure 15: Error Correction

The startup function of the PLC is to check the weather conditions. If there are any hazardous weather conditions, such as rain, snow, or wind the shutter will not open. This is to protect the equipment inside the dome. If the weather is good, the shutter will open and the dome will be operational. During the routine check of the system, the weather is always checked. If there is any sign of bad weather the shutter will close and remain closed for five minutes. The routine check also checks for any error in the domes rotation. If any error is detected an output signal will be sent to the motors to for correction. This routine check occurs every 5ms.
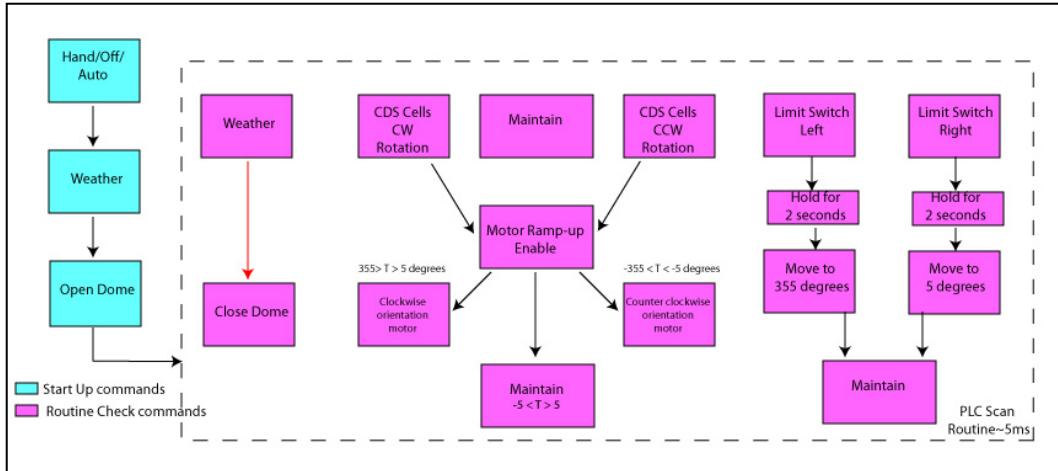
**Figure16: Routine Check**

5.3.2.2 PLC Code

The PLC is controlled by latter logic. The name latter logic comes from the format of the code. As shown below, the code takes the form of a latter containing multiple rungs. All rungs contain input functions, located on the left, followed by output functions on the right. Each rung is ether true or false. Depending on the input functions, if the rung is true the output will be energized. If the rung is false the output will be de-energized. The code is broken up into two sections which include the Dome Rotation and the Shutter Code. The Dome Rotation code controls the complete rotation of the dome and the Shutter Code controls the domes shutter to close if the weather is bad. Latter Logic does not allow for any comments to be displayed, therefore also included below is a table indicating the functions of each rung.

Table 3: Rotation Code Overview

Rung #	Inputs	Outputs if Energized
0	These rungs were produced by RSLogic for the initialization of the Input and Output cards that are used by the PLC	
1		
2	CCW_IN: True if the counter clock wise CdS array is hit by the laser.	CCW_OUT: Sends an output to the induction motor to rotate the

		dome in a Counter Clock Wise rotation.
	LATCH_CW: True if the limit switch for the clock wise rotation is not initialized.

LLSD_DN: True if the timer has counted up to the designated time. | If the LATCH_CW is latched it causes that part of the rung to be false turning off the motor. |
| 3 | CW_IN: True if the clock wise CdS array is hit by the laser.

LATCH_CCW: True if the limit switch for the counter clock wise rotation is not initialized.

RLSD_DN: True if the timer has counted up to the designated time. | CW_OUT: Sends an output to the induction motor to rotate the dome in a Clock Wise rotation.

If the LATCH_CCW is latched it causes that part of the rung to be false turning off the motor. |
| 4 | LIMIT_R: True if the right limit switch has been triggered. | LATCH_CW: Latches a bit indicating that the latch has been hit. This is used in rungs 2 and 5. |
| 5 | LATCH_CW: True if rung 4 is true. | TON: Sets a timer to allow for the induction motor to stop any momentum from the previous rotation. When the count is done it sets RLSD_DN high (see rung 3). |
| 6 | LATCH_CW: True if rung 4 is true.

CCW_IN: True if the counter clock wise Cds array is hit by the laser. | LATCH_CW: This unlatches the clock wise latch indicating that the dome is done rotating from the limit switch. |
| 7 | LIMIT_L: True if the left limit switch has been triggered. | LATCH_CCW: Latches a bit indicating that the latch has been |

|		
		hit. This is used in rungs 3 and 8.
8	LATCH_CW: True if rung 7 is true.	TON: Sets a timer to allow for the induction motor to stop any momentum from the previous rotation. When the count is done it sets LLSD_DN high (see rung 2).
9	LATCH_CCW: True if rung 7 is true. CW_IN: True if the clock wise Cds array is hit by the laser.	LATCH_CCW: This unlatches the counter clock wise latch indicating that the dome is done rotating from the limit switch.
10	Indicates the end of the latter	

LAD 2 - INITIALIZE --- Total Rungs in File = 11

| Rungs for 1771-IF module at rack 0, group 2, slot 0 |

Analog Input

0000

Block Transfer Write control block
N9:5
15

Block Transfer Read control block
N9:0
15

Block Transfer Write control block

```
─── BTW ───
Block Transfer Write
Module Type   Generic Block Transfer
Rack                              000
Group                               2
Module                              0
Control Block                     N9:5
Data File                        N9:74
Length                             64
Continuous                         No
            Setup Screen            <
```
(EN)
(DN)
(ER)

0001

Block Transfer Write control block
N9:5
15

Block Transfer Read control block
N9:0
15

Block Transfer Read control block

```
─── BTR ───
Block Transfer Read
Module Type   Generic Block Transfer
Rack                              000
Group                               2
Module                              0
Control Block                     N9:0
Data File                        N9:10
Length                             64
Continuous                         No
            Setup Screen            <
```
(EN)
(DN)
(ER)

0002

CCW_IN
I:001
17

LATCH_CW
B3:1
3

LLSD_DN
T4:1
DN

CCW_OUT
O:006
2

0003

CW_IN
I:001
15

LATCH_CCW
B3:1
2

RLSD_DN
T4:0
DN

CW_OUT
O:006
0

0004

LIMIT_R
I:004
0

LATCH_CW
B3:1
(L)
3

0005

LATCH_CW
B3:1
3

```
─── TON ───
Timer On Delay
Timer                    T4:0
Time Base                 1.0
Preset                     2<
Accum                      0<
```
(EN)
(DN)

42

Figure 17: Rotation Code

Table 4: Shutter Code Overview

Rung #	Inputs	Outputs if Energized
0	PRECIP: True if any precipitation is detected W_SPEED: True if wind speed is above designated amount	WEATH_BAD: Latches a bad weather bit SHUTTER_TIMER: Resets the shutter timer
1	WEATH_BAD: True if rung 0 is true.	CLOSE: Outputs a signal to the shutter motor to close the shutter SHUTTER_TIMER: Sets a timer to count down from five minutes
2	SHUTTER_TIMER/DN: True if the five minute countdown is complete.	WEATH_BAD: Unlatches the weather bad bit and check again. This allows, if the weather ever goes bad, to recheck the weather every five minutes.
3	WEATHR_BAD: True if the weather is not bad.	OPEN: Outputs a signal to the shutter motor to open the shutter
4	Indicates the end of the latter	

DOME CONTROL

LAD 3 - SHUTTER - Controls the opening and closing of the shutter --- Total Rungs in File = 5

Figure 18: Shutter Code

Monday, March 31, 2008 - 12:01:00
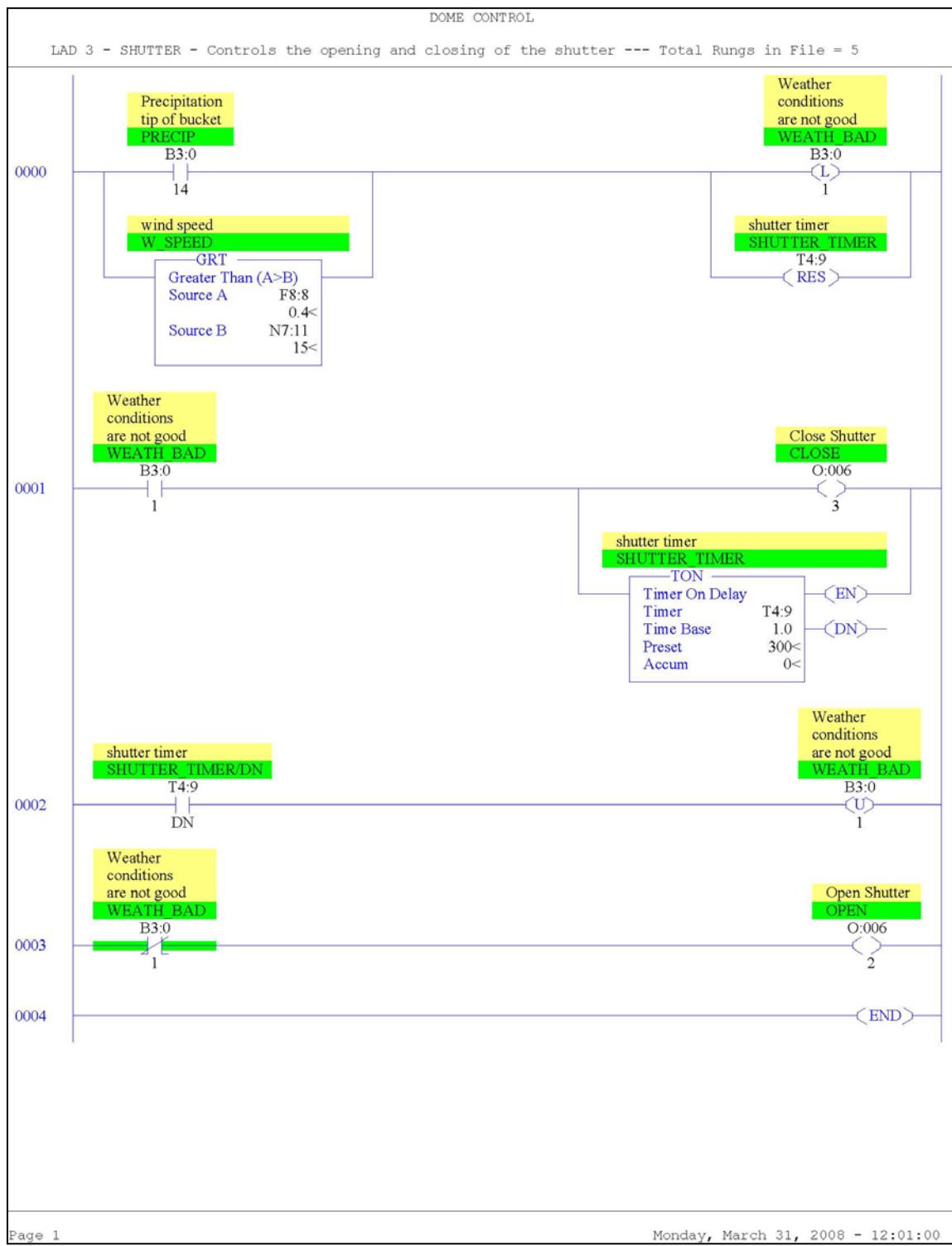
5.4 Project Implementation/Operation and Assessment

5.4.1 Current Implementation

Currently there are several things being implemented that affect the scope of our project. There is currently an electrician from USU facilities that is terminating all transmission lines into the dome panel that are landed onto control contacts. From the panel the electrician has bent conduit that leads to the different components of the observatory, pulled wire through the conduit and is in the process of wiring up power grid system. Along with the power installation process, individual module testing is taking place with the domes rotating program, weather program, and shutter program.

5.4.2 Finishing Work Process

After the wiring is completed the system testing will begin. The system will be tested with all integrated subsystems. Testing consists of several parts listed below

5.4.2.1 Power Failure

The goal for testing the Power Failure is to maker sure if there is any power loss the Uninterruptible Power Supply (UPS) will shut the shutter. This test will be performed by manually cutting off all power to the dome. The test will pass if the shutter closes.

5.4.2.2 Close Shutter/ Weather

The goal for testing the Close Shutter/Weather is to make sure upon any detection of bad weather the shutter door closes. This will be tested by manually tipping the rain bucket and spinning the wind speed sensor above the allotted amount. The test passes if the shutter closes.

5.4.2.3 Sensors

The goal for testing the sensors is to make sure the laser will have clean contact with the sensors around the entire dome. This test is to make sure that the dome, telescope, and laser are completely level. If there is a slight degree offset on any one of the above listed it could cause the laser to miss the CdS cell sensor array. If the array is missed this would cause the dome rotation to fail. If in any case the array does not sense the laser within a given time period of 60 seconds, an error light will illuminate asking for maintenance. This test will pass if the dome rotates a complete 360˚ while maintaining laser contact with the CdS cell array.

5.4.2.4 Dome Rotation

The goal for testing the Dome Rotation is to make sure the dome can rotate in a counter clock wise and clock wise rotation upon request from the sensor array. The test will pass if the laser is manually pointed on individual sensor sections and the rotation occurs promptly and in the correct rotation.

6.0 Telescope Subsystem

6.1 Existing Hardware/Conditions Telescope Subsystem

6.1.1 Telescope Subsystem

The telescope subsystem is part of the Rocky Mountain Space Grant Observatory project. It will be used by the interested public to view astronomical objects such as stars and planets. This project will allow the telescope to be accessed by a remote computer which will give interested youth access to a science experience that they otherwise would not be entitled to. Hopefully, using the telescope will help interest them in pursuing a science based education.

The telescope that is being used for the Rocky Mountain Space Grant Observatory is the Meade LX200R 14". When the project began it was located in the basement of the engineering lab building. It was not set up and there was no user's manual. Later, a user's manual was acquired and the telescope was properly set up in the dome. The initial setup included: taking the telescope parts out of the box, setting up the tripod, connecting the telescope body to the tripod, plugging in the correct cables, and aligning the telescope by centering specific stars. Proper implementations of a camera and software package that connect to the telescope now allow the telescope to be controlled remotely by a computer. This includes both moving and focusing the telescope.

The telescope subsystem consists of the telescope itself, a CCD camera, vibration control, hand box control, a computer, telescope control computer software, camera control computer software, and connecting cables. The main block diagram for the system is shown in Figure 19 below. The project included selecting the main components of the system, designing the connections between components to ensure that data was held intact throughout the entire system, implementing the design, troubleshooting the design to make it work properly, and testing the final subsystem to make sure everything works.
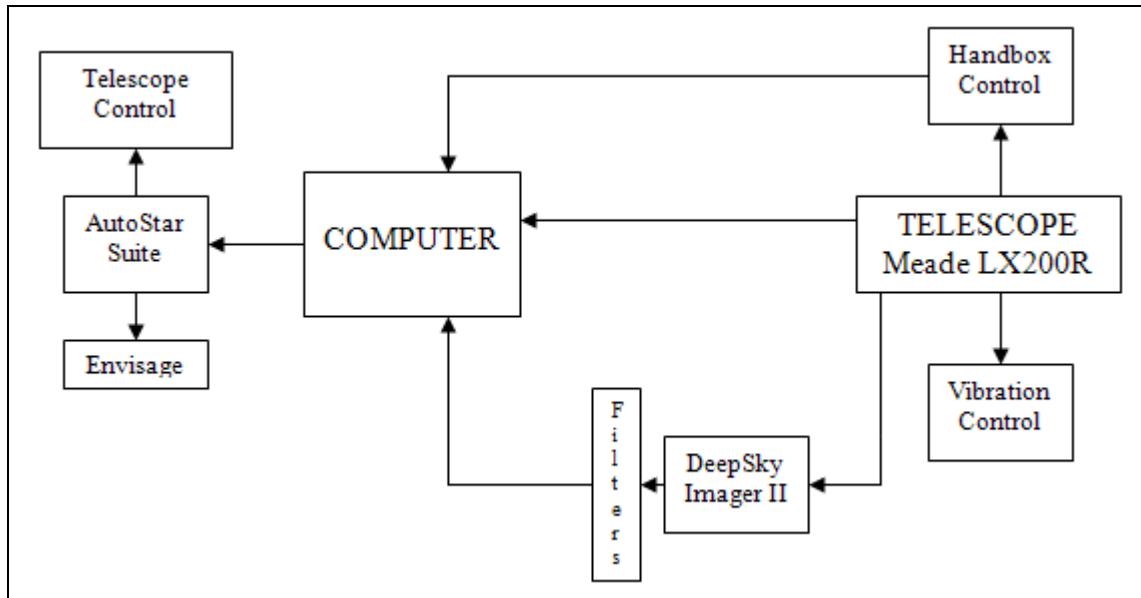
Figure 19: Telescope System Block Diagram

6.1.2 Location/Operating Conditions

The location of the telescope is in a dome on the roof of the Engineering Lab Building and the control computer is currently located in the room below the dome. The dome currently is operated by switches located inside the dome that activate motors to open, close, and rotate the dome. These conditions require that someone be physically present to move the dome with the telescope which means that total remote access of the telescope subsystem is not possible at this time. The fact that the telescope and computer are in different rooms has required that the cables interfacing the telescope and camera to the computer to be at least 7.62 meters long.

6.2 Design Constraints

6.2.1 Operating Software

The Rocky Mountain Space Grant Observatory was designed to be able to be used by the public who will not have access to the telescope itself. This requires that the telescope be able to be completely controlled by a computer at a different location. This control must include being able to slew the telescope from one star to another, being able to focus the telescope, and being

able to control a camera hooked up to the telescope. Since most of the users of the telescope won't be astronomy specialists, it is vital that the computer programming provides a way to make the telescope find selected stars on its own. This would make the telescope more appealing to use which is one of the main considerations for the project since it is being used by the public to promote science learning.

6.2.2 Vibration Control

Photographs from the CCD camera on the telescope are sensitive to vibrations from the surrounding environment. Therefore some mechanism to reduce the vibrations felt by the telescope and subsequently by the camera needs to be implemented. The vibrations need to be reduced to the point that they don't adversely affect image quality.

6.3 Designs

6.3.1 Software Selection

Since the telescope is to be operated remotely, a software package that was able to control the telescope and camera had to be selected. The software that was selected is the AutoStar Suite. It is able to completely control the telescope and camera. It has a star map incorporated into the software. A star can be selected on the map and the software will move the telescope to that star's location. The program also allows the user to manually move the telescope. This allows other objects not on the star map to be viewed remotely. This is done using the remote hand-box module of the software. This is shown in Figure 20. The CCD camera that is used is also controllable with the software. The exposure time, quality levels of individual pictures that are compiled together, and the number of pictures that are compiled for a final photograph are all remotely controllable. The Envisage module of the software that controls the camera is shown in Figure 21.
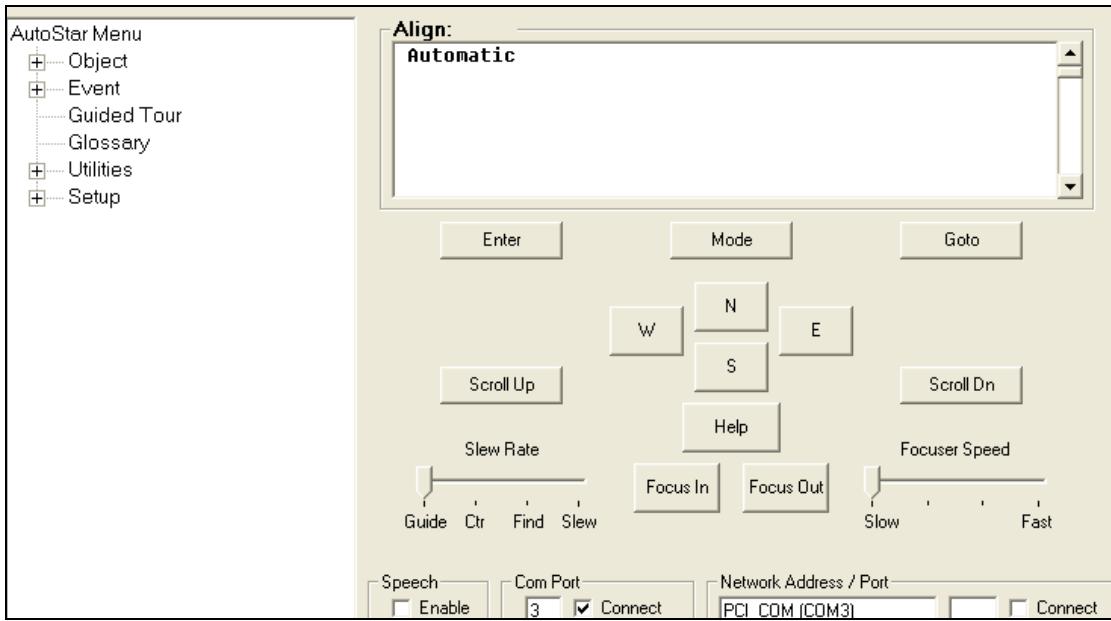
Figure 20: Remote Handbox
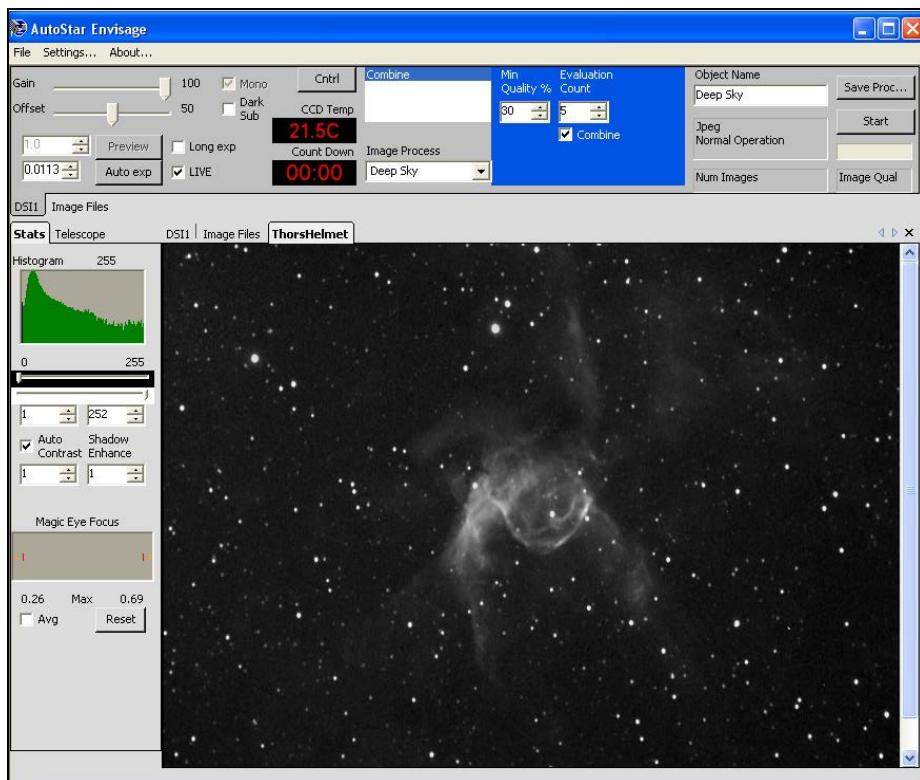
Figure 21: Envisage Imaging

6.3.2 Camera Selection

The camera that was selected to be used is the Deep Sky Imager Pro II made by Meade. It

was selected from several possibilities. The main choices were narrowed down to the Deep Sky

Imager II, the Deep Sky Imager Pro II and the Orion Star Shoot Deep Space Imaging Camera II. These three cameras had similar resolution and exposure times. They also all operated by using a USB cable. This was important since they used the 5 volts supplied by the USB cable for their power needs. This meant that none of them operated on battery power which was one of the telescope subsystem design constraints. The main reason that the Deep Sky Imager Pro II was chosen was that it came with the AutoStar Suite software which is designed to control the camera as well as the telescope. The Orion camera didn't come with software like this. The other Deep Sky camera would have also been a good choice, but the pro version has several added features.

6.3.3 Vibration Control

A major factor in telescope photography is vibration control. Even small vibrations can cause a photograph to be blurry. This is due to the fact that the images being photographed are light years away and extremely magnified. It was determined that placing vibration control pads under the tripod of the telescope reduces the vibration levels down to a usable level that doesn't severely affect the picture quality.

6.3.4 Cable Interfacing

The interfacing between the different components of the system was an important part of the design process. If any of the interfaces didn't transmit data properly without data loss or corruption then the system wouldn't be able to communicate from one device to another properly. The main ways that the interfaces could corrupt data would be due to the voltages on the lines dropping below readable levels due to the lines being too long or due to reflections or rejections that arise from improper impedance matching. Great care was taken to ensure that this didn't happen on any of the interfaces or cables used in the design. A flow diagram showing the connections and cables is shown in Figure 22.
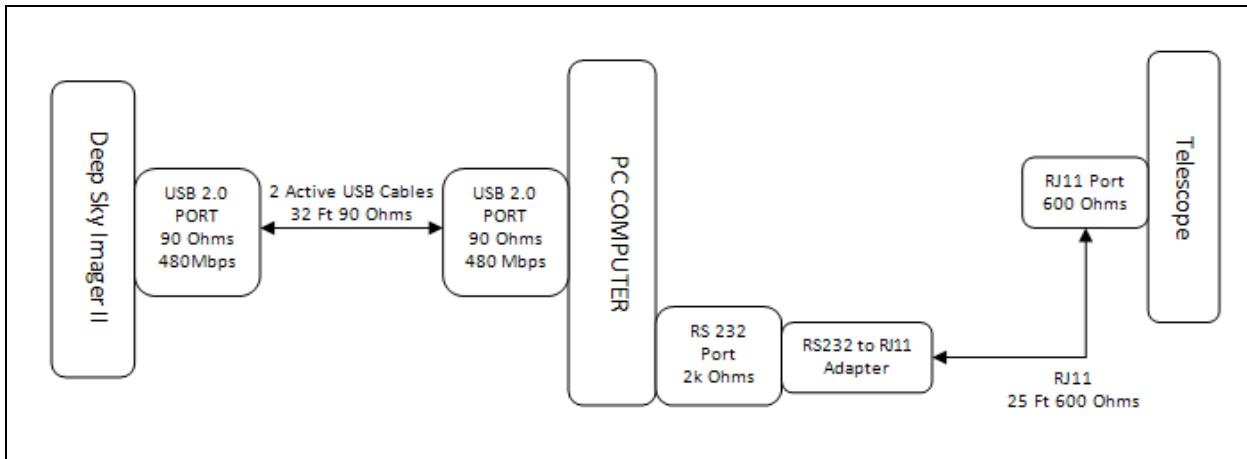
Figure 22: Interface Flow Diagram

The design used a USB cable to connect from the camera to the computer. The use of a USB cable was a potential problem because a normal USB cable is only able to reach for 5 meters before it can no longer properly transmit data. This is because the maximum round trip delay for a USB cable is 26 ns and the delay in a USB cable is 5.2 ns per meter. The voltage that USB cables use to transmit data falls below the 2.8 to 3.6 voltage range for cables longer than this. The cable was required to be a minimum of 7.62 meters to reach from the telescope camera to the computer. To overcome the length issues so that the camera would be able to communicate properly, an active USB extension cable had to be used instead of the normal passive USB cables. This allows for two 5 meter cables to be hooked together without the same problems. The reason the active USB cables didn't run into the same issue is that they double the signal voltage and act as buffers for the signal in both directions so that the round trip delay time is met. The impedance of the USB cable and the USB ports were matched at 90Ω so no further impedance matching was required.

The connection between the telescope and the computer used a combination of RS232 and RJ11 phone cords. A RS232 port had to be selected to be installed on the computer since there wasn't one available. The port that was selected fit into an I/O expansion slot on the

motherboard of the computer and was Windows XP compatible. A 3 wire RS232 connection is used by the telescope. Since this is the case, and not all nine connections on the RS232 would be used, a DB9 to RJ11 adapter was selected to be used to plug into the RS232 port on the computer. Then the RJ11 phone cable was selected to be used to connect between the adapter and the telescope. The RJ11 phone cord was selected to be 7.62 meters long. It had to be this long to reach between the computer and the telescope since they are not in the same room. The RJ11 phone cord is able to transmit data without out the voltage dropping below critical levels for this length of cord. The voltage levels on RS232 are -3 to -15 volts for logic 0 signals and 3 to 15 volts for logic 1 signals. The impedance of the RJ11 phone cord and the ports it connects to are matched at 600Ω so no further impedance matching was necessary.

6.4 Implementation

6.4.1 Computer Software Configuration

The Autostar Suite required some setup for it to work properly. The correct latitude and longitude of the EL building had to be input so that the software would be able to properly locate stars. The Latitude is 41:46:47 N and the Longitude is 111:50:59 W. Figure 23 shows a screen shot of latitude and longitude being setup. The settings for the com port also had to be set up so that the computer and the telescope could communicate properly. The settings were 9600 baud rate, 8 data bits, no parity bit, 1 stop bit, and no flow control. Figure 24 shows a screen shot of the com port settings being set up. An RS232 port had to be installed on the computer since one wasn't available. This port is used to connect the telescope to the computer. Section 5.c.iv explains the cable setup in depth.
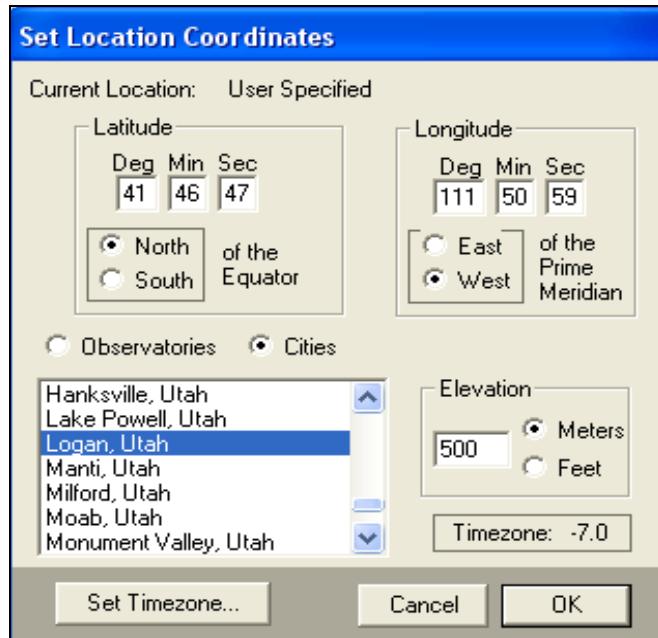
Figure 23: Setting up Location Settings
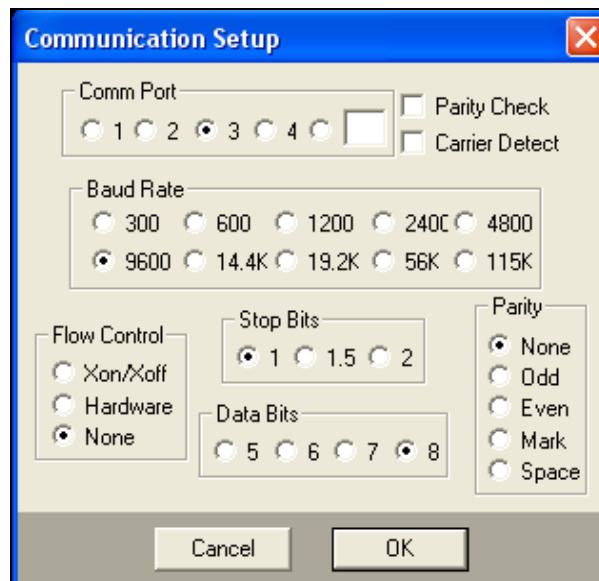
Figure 24: Com Port Settings

6.4.2 Camera Installation

The camera sits where an eyepiece would normally go on the telescope. The main issue

to overcome in installing the camera is to make sure that the telescope mirrors are set up in such

a way that they project the image for the right focal length. When the camera sits in the eyepiece

slot, the focal length is different than that of most eyepieces. We found that a 25mm eyepiece

has the same focal length as the camera and can be used to focus the telescope correctly for the camera.

6.4.3 Floor Mounting/Vibration Control

The telescope is currently mounted on a tripod that sits on the floor. This holds the telescope steady and there is not a risk to the telescope tipping over while in use. The biggest problem with the mounting is that it is not permanently in place. The tripod could be moved around by someone up in the dome. Moving its location would interfere with the telescopes ability to accurately locate stars using it's built in data base. This is because the telescope has to be aligned each time it is moved. If it isn't realigned after someone moves it then it isn't able to locate stars accurately.

One of the biggest problems that had to be overcome when using a computer to control the telescope and collect photographic data was vibrations. The vibrations would cause stars to jump around on the screen when photos were being taken. To help stop this, vibration control pads were installed under the tripod of the telescope. By mounting the telescope on these pads the vibrations were lessoned, but not entirely eliminated. Since the operation of the telescope is still not completely automated, people walking around the dome are a major cause of the vibrations. When the project becomes completely usable offsite these vibrations will no longer be an issue.

6.4.4 Telescope Alignment

The telescope system comes with the ability to slew the telescope to stars that are selected either with the hand-box on the telescope or with the Autostar Suite on the computer. For either of these methods to work the telescope first has to be aligned so that it knows where it is in reference to the stars that it has programmed into the database. The alignment process

includes the telescope finding north, finding where it is level, downloading its approximate GPS location, and having the user center at least two finder stars in the center of the telescope viewing area. The more stars that are centered the better the alignment will be and the less future users have to adjust the location of the telescope to be centered exactly on the object they are trying to locate.

6.4.5 Equatorial Mount

The current method of moving the camera to track a star during a photographic session requires the use of two motors. One moves the telescope in azimuth and one in altitude. This makes perfect tracking hard which can lead to streaking on the final photograph. A way to correct this problem would be to install an equatorial mount. One type of equatorial mount is a Meade Superwedge. The Superwedge would allow the axis of the telescope to line up with the axis of the earth. Then only one motor would be required to track a star and the streaking effect would be eliminated.

7.0 Final Scope of Work Statement

7.1 What Has Been Done

Throughout the course of the semester we have designed, implemented and tested multiple parts of the project. The latter logic code that will run the dome has been designed tested and reconfigured throughout the semester and is ready to be tested on the entire system. The CdS cell sensors was thought of earlier in the semester but was scratched to pursue what was thought to be a better way. Half way through the semester we realized that our first idea would be the better way to go and so we finished designing what we had started earlier in the semester. The completed circuit is shown in Figures 25 and 26.
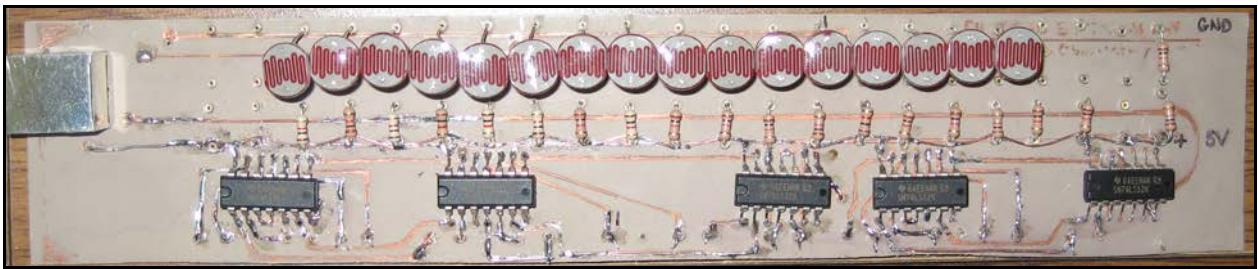
Figure 25: Sensor Circuit Front
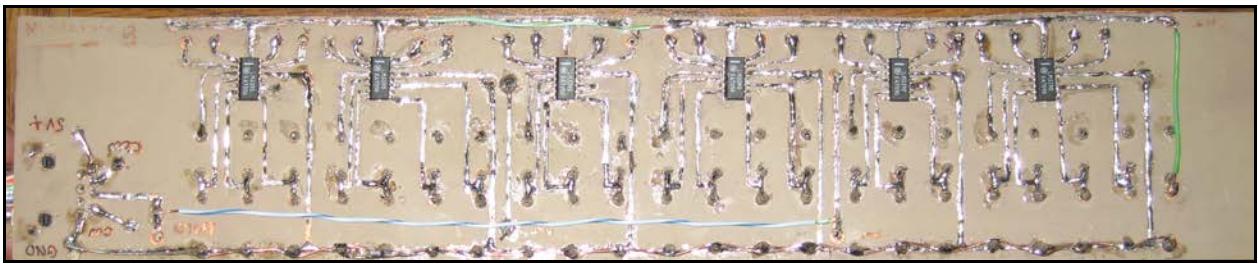
Figure 26: Sensor Circuit Back

7.2 Lessons Learned

Many mistakes have been made throughout the course of the semester, all of which we have learned something from. One of the biggest lessons learned is to keep good and detailed documentation. There were a few times when already engineered information was reengineered do to a lack of documentation. If documentation was concurrently produced during the engineering process it would have saved some time when that information needed to be reviewed.

The Latter Logic code written for the PLC, just like any code, has a different type of language and its fair share of quirks. The hardest part about learning a new programming language is to understand how the code works and how to trouble shoot it when there is undesirable results. Even with user manuals a good amount of engineering hours were dedicated to learning and producing the desired code to operate the PLC.

The Rocky Mountain Space Grant Observatory project incorporates multiple groups all working on different parts, but all of us were working towards the same goal of getting the observatory to be completely automated. Communication is an essential part of a group project to ensure that all jobs are understood, executed, and done right. Each group may be working on different part of the project, but all subgroups still needed to use the same computer and work space to get their jobs done. Communication was essential to ensure that everyone had the space, equipment, and time needed to complete each part of the project.

7.3 Power Installation Issues

The biggest critical path for this project was the power installation. The dome is located on government property which meant that the universities electrician was needed to install the power throughout the dome. After drafting up the power grid facilities were contacted to install the system. At one point it was mentioned that it could take up to a year and ten thousand dollars for the electrician to complete the job. After some persuasion with facilities an electrician came and installed the power grid. The problem was the timing issue and cost associated with the installation. Final testing could not take place until all of the power was installed. Because of the long time period for the power grid to be installed, only individual testing could take place. This was a good lesson to learn for future use. The lesson learned is that outsourcing anything can take quite some time. It is in the best interest of any project to contact the provider well in advance in order to schedule any installation processes.

8.0 Maintenance

8.1 Duties

Because the Rocky Mountain Space Grant Observatory is part of the Space Grant Internet Telescope Network (SGITN), there will be a need to have someone there to maintain the observatory to ensure that it is functioning properly and will perform any fixes that may need to be done to the dome. Some of the maintenance duties will consist of: Observatory Scheduling, Telescope Alignment, Dome Alignment, Regular Maintenance, Weather Checking and Computer Maintenance.

Observatory Scheduling: There are multiple observatories that are part of the SGITN and because of that, there is a need to have someone schedule the dome for observations, in this way we can eliminate multiple users from running the dome at the same time.

Telescope Alignment: The telescope is not always 100% accurate in its movements which will cause the telescope to become un-aligned over a period of time. To correct the inevitable, the maintenance person will be trained in the operation of the telescope and will perform regular alignment maintenance. The Telescopes batteries should be replaced on a regular basis so that in the event of a power loss the telescope will be able to remember its current position and will not have to be realigned.

Dome Alignment: If the dome is unable to keep up with the telescope while tracking an object, the PLC will give an error back to the user, notifying them that the dome is no longer aligned. Observatory maintenance will go to the observatory and perform any manual realignment necessary.

Regular Maintenance: Observatory maintenance will have a routine check to perform before each scheduled observation as well as monthly and weekly maintenance checks. Checking the

overall functionality of the dome to ensure that no or little maintenance will need to be done while an observation is running, that means that all sensors need to be tested to make sure they are working, test the laser to make sure it is aligned and functioning properly, test all motors and look for and fix anything that may be hazardous to the equipment while under operation. The weekly and monthly tasks may change as needed but should include all of the before mentioned items, so that when the observatory is needed there will be more time to fix any issues.

Weather Check: Part of scheduling the dome is to be able to give feed back to the desired user about the weather and what to expect. Knowing what to expect from the weather will give the observatory maintenance the ability to give users a go no go for observations and time to check the weathers sensors to ensure they are functioning properly so that no equipment gets damaged.

Computer Maintenance: The computers software should be updated regularly and so the user should be familiar with the software and should be ready to install any new updates when they are distributed. The computers operating system (Windows Xp) needs to be kept up to date on critical patches released from Microsoft, all new critical patches are released on the second Tuesday of every month. The virus scan should be checked at least once a week to make sure that its virus definitions are up-to-date. The computer's hard drive should be imaged onto a separate hard drive once every three to six months, so that in the case of a hard drive failure the system is saved and can be quickly brought back online with little effort.

8.2 Dome Instructions

A set of instructions will be written for every sub system of the observatory which will give the user step by step guidance of what to do under certain circumstance. The circumstances that will be addressed are for the observatory dome subsystem and will address the following

issues: Power Failure, Laser Failure, CdS Sensing System Failure, PLC Failure, and Computer Failure. There is also instructions for Updating the Website.

Power Failure: In the event of power failure the UPS system should allow enough power to shut the shutter. If a power failure does occur, maintenance needs to check to make sure that the shutter did automatically shut, when the power comes back on maintenance needs to check all equipment, realign dome and telescope if needed, and continue any observations that may have been running at the time of the outage.

Laser Failure: If the laser quits working then maintenance should: Check power to the laser using a volt meter, check connection to laser. If the previous two items did not fix the issue then the laser should be replaced and the new laser should be mounted and aligned.

CdS Sensing System Failure: If the sensor circuit fails to work then maintenance should: check the power to the circuit for +5V, if there is power to the circuit then maintenance will have to start the excruciatingly painful process of checking each component of the circuit. In order to check each component, maintenance will be provided with the circuit diagram and with a voltmeter to check the components. When the failed component has been found it will need to be replaced with the same functioning part.

PLC Failure: If the PLC is not functioning properly the code may need to be reloaded. If the code has been reloaded and the PLC is still not performing correctly it may need to be restarted. If the previous two items did not fix the issue, then maintenance will need to refer to the PLC user's manual which will be provided.

Computer Failure: If the computer fails to start then maintenance needs to either have a technician locate and fix the issue or maintenance needs to fix it their self. If any data is lost or if the hard drive has been replaced, then the image of the hard, which should have been made every

three to six months, will be placed back on the hard drive. If the hard drive was never imaged then maintenance will have to reinstall all software and get the telescope running again.

Updating the Website: The project website can be viewed at http://rmspacegrant.googlepages.com. If additions or edits need to be made they need to be performed by going to http://pages.google.com. The login name is rmspacegrant and the password is aggieobs. Included are some helpful tips for updating the website.

To create a new link first select the page you would like the link added to on the main site manager page. Place the curser where you would like the link to be and select the "link" button on the left side of the tool bar. This will bring up four options for the type of links you can select from. "Your pages" will create a new page in google pages and link it to your current page. "Your files" allows you to browse for what you would like to add to the page i.e. a word document, photo, or other file. "Web address" would create a link to another website. "Email address" will save a link to an email address that when clicked on will open a generic email editor.

The "text to display" box at the top of the link editor window if where you enter the title you would like to view on the webpage. For example if you are creating contact information with email address you would put "John Smith" as the text to display and john.smith@gmail.com as the email address link.

Always remember to click on the publish button in the upper left part of the screen to save any changes. If you forget to do this it will display "unpublished" or "in revision" next to the page in the main site manager page as a reminder.

9.0 Conclusion

The Rocky Mountain Space Grant currently owns a dome and telescope located on the roof of the Engineering Laboratory building. The overall objective is to design a system that allows for remote access from a Personal Computer to control the telescope and have the dome follow any rotation thereof, allowing for an unobstructed view into the night sky. The dome must also be able to close when any bad weather is detected in order to protect the equipment inside.

Engineering steps that have been completed include the designing of a complete operational system, installation of individual components, and necessary control programs written. Along with all installation individual testing of components, such as the laser, CdS sensor array, weather program, shutter program, and rotation program have been completed.

Currently the power grid is being installed. This includes all of the conduit and wiring of high voltage components such as power from circuit breakers to the PLC, relays, motors, switches, and transformers to the power supply.

The completion of this project is a little behind schedule do to the critical path of the power installation. After the power installation is complete the final testing will begin.   The final testing is the last part of the project and after completed, the project will be function according to specifications from the users. The total cost of the project, including all subsystems, has been accepted and approved by the customer.

Both the design and report are engineered to meet customer specifications. Any necessary steps will be taken to ensure that the customer is completely satisfied with the implementation of the project.

10.0 Special Thanks To Sponsors

We would like to thank our many sponsors for making this project possible. We would like to thank ATK and Allan Bradley for the donation of the PLC and operating software. We would also like to thank Rocky Mountain Space Grant and USU for the financial and design support throughout the project. Without these sponsors this project would not be possible.